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Ilse Schreiner and Donald Nafus

ADAP PROJECT
Agricultural Development in the American Pacific
Pacific Land Grant Programs

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PREFACE

Within the jurisdiction of the United States Land Grand System, there are five institutions located on islands in the Pacific Ocean. These include the University of Hawaii, the University of Guam, American Samoa Community College, Northern Marianas Community College, and the College of Micronesia. The latter serves the Federated States of Micronesia, the Republic of the Marshall Islands, and Palau. Recently, the United States Congress allocated money through the United States Department of Agriculture Cooperative Extension Service to enable these institutions to undertake cooperative programs to better serve the region. This program was named the Agricultural Development in the American Pacific, or ADAP.

Agriculture in the Pacific Islands within the ADAP project differs markedly from that on the mainland United States. The islands share many crops, pests and problems that are not present in the United States. Information on certain pests is often lacking, and outside of Hawaii, manpower and funds to work on them is scarce. Information networks to train farmers and transfer technology is often poor or nonexistent. To deal these difficulties several projects were begun under the ADAP umbrella. One of these was the Crop Protection Task Force. The mission of this group was to bring together the crop protection personnel of the five land grant institutions to work on projects of common interest and to share their knowledge. Several priority areas were identified by the Task Force. These included the development of Integrated Pest Management programs for high value horticultural crops, improved biological control within the region, development of information on traditional root crops and their pests, and better exchange of information between institutions, researchers, extension agents, and farmers.

This conference is an outgrowth of this mission, and is the second conference organized by the ADAP Crop Protection Task Force. The goals of the conference were to report on progress in the joint projects and to facilitate information exchange between ADAP participants and crop protection personnel from outside island nations with similar problems. A special effort was made in this second conference to include extension personnel from the islands within the ADAP region to expose to them to current research work being done by their land-grant institutions. Agricultural workers from American Samoa, Australia, Fiji, Guam, Hawaii, Kosrae, the Marshall Islands, New Zealand, Saipan, Palau, Pohnpei, and Yap attended. This document is the proceedings of this conference. It is intended to provide a formal record of information exchange that will be accessible to future workers in the region and to agricultural workers who could not attend. We hope the information contained within will continue to serve the needs of the region in the future.

Ilse Schreiner
Donald Nafus

GUIDELINES FOR BIOLOGICAL CONTROL PROJECTS IN THE PACIFIC

D.F. WATERHOUSE

ACIAR, GPO Box 1571, Canberra, ACT, Australia, 2601

ABSTRACT To achieve maximum benefits from biological control introductions it is necessary to choose organisms with some care and ensure that they are released without contaminants. Biological control work in the Pacific region has been somewhat haphazard in the past. A series of guidelines to ensure safe and effective release of biological control organisms was requested by the South Pacific Commission from the Australian Centre for International Research. Two series of guidelines, on testing for host specificity and on safe introductions of biological control agents were presented at this meeting for comment. Methods for testing of host specificity of insects introduced for the biological control of weeds is considered in some detail, with additional comments on the host specificity of of parasitoids and predators of other insects. To introduce biological control agents safely, it is considered to preferable to breed the agent though on or more, but not many, generations in the laboratory to ensure that it is free of contaminants. Additional comments on methods to ensure the release of pure cultures of the biological control agent are detailed.

The South Pacific Commission (SPC) enlisted the assistance of the Australian Centre for International Research (ACIAR) to have simple Guidelines drafted for 'Biological Control Projects in the Pacific. ACIAR arranged for Dr D.F. Waterhouse to coordinate this task. The guidelines that follow, numbers 5 and 6 are the most important of the complete set of ten. They were warmly supported by SPC's Regional Technical Meeting on Plant Protection in February 1990 and, soon after, endorsed for a trial period of two years by SPC's 9th Conference of Permanent Heads of Agriculture and Livestock Services. Their presentation at this ADAP meeting is designed to provide wide circulation and it is hoped that experience with them will indicate whether modifications are needed before formal adoption.

Guideline 5. Host Specificity

5.1 When selecting biological control agents for introduction to a new country it is highly desirable to choose those that are narrowly specific to the pest or group of pests they are intended to attack. This is to avoid any possible adverse effects on non-target organisms. The importance of correct identifications for both the pest and all candidate natural enemies must also be stressed.

5.2 It must be strongly emphasised that, when appropriate agents are selected and proper procedures adopted, biological control is an extremely safe procedure. Indeed there is not one single documented case of an agent that has satisfied the host specificity criteria described below causing unexpected significant damage to non-target organisms, despite the fact that, over the past 80 years or more, many hundreds of agents have been introduced to various parts of the world. In the earlier part of this period, restrictions were far less rigorously applied than they are now, but still problems have been virtually unknown. Today, safety considerations are certainly applied much more stringently to the introduction of biological control agents than to the vastly greater volume of importations of other living organisms for commercial purposes.

5.3 Host specificity is considered in some detail because it is important that people bearing the responsibility for approving imports and releases of biological control agents should feel quite confident about the safety of a decision to give approval, after due attention has been paid to established procedures.

5.4 There are several ways in which information on host specificity may be obtained:

(a) A detailed study should be made of the biology and behaviour of a candidate control agent. This will often permit sound conclusions to be drawn about its probable host restriction in a new country, while information from species closely related to the candidate agent may also provide valuable supplementary data.

(b) Where possible, careful field observations of the range of species attacked should be made in countries where the candidate agent already occurs. If desirable animals and plants there are unaffected by the agent, it is most unlikely that these same species will be affected in a new country. Reliable information of this sort may be available in the literature in some countries. Only species or varieties that have never been exposed must then be viewed as requiring further checking. Information from any countries in which the agent has already been established for biological control is also highly relevant.

(c) If data from the studies listed in (a) and (b) are considered inadequate or are not available, tests can be performed to give the candidate agent an opportunity to attack any non-target hosts of economic or other importance that have not been adequately challenged where the agent already occurs.

5.5 It is convenient to consider, individually, methods for evaluating the host specificity of candidate agents that attack (a) weeds and (b) those that attack invertebrate pests.

Host specificity of organisms which attack weeds

5.6 Feeding Habits

Organisms (particularly, insects, mites or pathogens) that attack plants may be either:

(a) monophagous (which attack only one host),

(b) oligophagous (which attack only a group of closely related plants),

(c) polyphagous (which attack more than one group of plants).

5.7 Contrary to popular belief, only a minority of plant-attacking organisms are polyphagous, the majority being oligophagous or monophagous. A number of quite specific conditions must be satisfied before development to reproductive maturity on a plant can occur. For example, certain specific chemicals must be present to attract the insect and induce oviposition and feeding, nutritional requirements must be met, the plant surface must be smooth or hairy depending upon the particular behavioural requirements of the insect, the stem must be thick enough if it is a stem borer and so on.

5.8 Plants that are closely related are far more likely to have the correct combination of attributes than those that are less closely related. Indeed, it has been found that, if an insect attacks a small number of plants (i.e. it is oligophagous), those plants are almost always closely related. It is almost unknown for quite unrelated plants to be unexpectedly attacked by biological control agents following proper testing.

5.9 Ideally biological control agents should be monophagous, but they may be oligophagous if none of the group of closely related plants attacked is of economic, cultural or conservation importance. In general, polyphagous species are unsuitable for introduction as biological control agents.

5.10 For an insect to attack and develop to reproductive maturity on a plant, a number of requirements have to be met sequentially:

Oviposition

(a) The egg-laying female must first be attracted to the environment in which the plant is growing and then to the plant itself by sight, smell, or both. Sometimes females are unable to recognise that certain plants would serve as good hosts. This is because of the absence of token chemicals and hence they pay no attention to them.

(b) Once attracted, the female has to be stimulated to lay eggs. Oviposition is frequently induced by the particular chemical composition and/or surface texture of the plant, sometimes by its colour, and sometimes by environmental factors, such as whether it is growing in sunlight or in shade.

5.11 Egg hatch. In some cases, chemicals in unsatisfactory host plants can prevent eggs hatching.

5.12 Larval development

(a) Before they will start feeding, newly-hatched larvae must receive from the plant at least two sets of different and quite specific chemical messages. One set triggers the biting reflex and the other the swallowing reflex. Often larvae will leave an unsatisfactory host plant and finally die unless they find a suitable host.

(b) Even when these two requirements are met, deterrent chemicals may prevent feeding, the larvae may suffer from the plant lacking the correct balance of nutritive materials necessary for development, or toxic materials present in the tissue may actually kill the larvae. Such malnutrition or toxicosis may result in the larvae dying after a period of apparently normal feeding, or after pupation, or pupae producing adults that are unable to reproduce.

(c) Physical barriers (hard or waxy cuticle, hairiness, etc.) may prevent larval feeding.

5.13 Adult feeding

If adults are produced and these also feed on the host there are four possibilities:

(a) feeding and reproduction are normal,

(b) feeding is normal, but reproduction is reduced or inhibited,

(c) feeding is abnormal and reproduction is reduced or inhibited,

(d) no feeding occurs.

Experience shows that only plants in category (a) are normally at risk.

5.14 If a larva or adult feeds only briefly on a plant, but is unable to complete its life cycle, it is a clear indication that the plant is not a satisfactory host. Casual feeding of this type should not exclude release of the natural enemy as a potential biological control agent. Special consideration may need to be given to some insects where brief feeding may still cause some damage, for example virus transmission by aphids.

Selection of Plants for Testing

5.15 As indicated earlier, the most relevant information on host specificity of a potential agent species comes from careful observations on the range of plants it attacks in its country of origin, or in some other country in which it has become established. Experience shows that it is safe to assume that plants of economic or other importance that have not been attacked under these conditions are not attacked in a new country. However, when there are crops (or unusual cultivars) or other valued plants in the new country that have never been exposed to the biological control agent it may be advisable to carry out tests to determine whether such plants are safe from attack.

5.16 In addition to testing plant species never before exposed to attack, valuable information on host specificity can be obtained by testing plant species that are closely related to the weed. If none at all is attacked, or if attack occurs on only the most closely related, the insect very probably has highly restricted feeding requirements and hence is very unlikely to attack plants of economic or other importance which are unrelated.

5.17 The practical procedures for testing are simple if this can be done in the country of origin, since no quarantine facilities are necessary. The main problem is that the species or varieties of plants to undergo testing may not be readily available and there may be reluctance on the part of the agricultural authorities to approve their introduction for testing purposes.

5.18 Sometimes, potted plants of the species to be tested can be exposed in the field close to hosts with heavy natural infestations. If any damage is observed it is essential to determine carefully whether this has been caused by the candidate agent and not by polyphagous insects, such as grasshoppers. Any significant attack by the agent, especially if it completes development, will exclude its further consideration. More frequently, potted plants are put into cages, together with the potential biological control agent and its host weed and any pattern of damage observed daily for as long as is required to determine whether test plants can be infested, generally at least 7 days, depending on the biology of the agent. Several plant species can be tested at a time and all trials should be repeated at least 3 times. If it is not possible to use vigorously growing pot plants, trials may be performed using portions of fresh terminal growth cut from the test plants. By means of this somewhat artificial and severe test of specificity, most test plants can be rapidly eliminated as potential hosts if no feeding is observed. Very occasionally chemical changes in cut foliage lead to attack giving an artificial positive result. If this is suspected there is no alternative to testing growing plants in pots.

5.19 When any larval or adult chewing or sap sucking occurs, that plant species is then subjected to repeated and more rigorous testing to determine whether it is capable of supporting larval development and, if so, whether any adults that are produced are capable of reproduction. It is always important to include some plants of the weed as controls and to ensure that the agent has produced a significant level of attack on them, thus demonstrating that the cultures are vigorous enough and that the conditions are suitable for the agent to respond to its normal host.

5.20 When it is not possible to carry out such tests in areas where the candidate agent already occurs, the screening tests must be performed in the country of destination. Secure quarantine conditions must then be available to ensure that the agent does not escape. Although more laborious, this procedure has the advantage that the varieties of the crop or other valued plants in the country of destination are readily available.

5.21 A major problem with cage tests is that insects often do not behave entirely naturally under confined conditions. In fact, they are far more likely to lay eggs on, and chew or suck briefly on a plant that they would not normally select under field conditions. Thus, cage tests represent the extreme and a plant not attacked in cage conditions will not be attacked in the field. Because of this tendency, exclusion of an effective agent should not depend solely on seemingly positive results obtained under such unnatural conditions.

Host specificity of fungi attacking weeds

5.22 There is growing acceptance that some pathogenic fungi are sufficiently host specific to be used safely as biological control agents. Procedures for evaluating their specificity follow a pattern somewhat similar to that for insects, with special considerations given to different spore types and possible alternative hosts. However, the quarantining of these agents is more difficult and nearly all testing would be carried out in their country of origin or in specially-constructed, high-security facilities.

Host specificity of agents attacking insect and mite pests

5.23 Far fewer problems have been encountered concerning the specificity of agents attacking insect and mite pests than with agents attacking weeds. This is probably because in their case far fewer non-target organisms are usually considered to be at risk. The potential unintended victims are mainly beneficial insects (such as already introduced biological control agents) and a few generally showy or rare insects (such as certain birdwing butterflies) that are considered to be of special importance. With available knowledge it is not yet possible to assess the risk to the majority of native species of no currently recognised economic, cultural or aesthetic importance but which are desirable from a conservation point of view. The risk to these species is seldom considered significant, but it is not easy to establish this.

5.24 Most parasitoids and predators that actively seek out their hosts respond to specific environmental cues that direct them to the appropriate plant habitat where the hosts are normally found. Thus an agent adapted to search a vegetable crop may not visit the tree canopy or the ground litter.

Parasitoids

5.25 There is abundant evidence that many introduced parasitoids have produced economically important reductions in pest abundance. The majority of primary parasitoids appear to be adequately host specific but there are very few instances of attempts having been made to challenge non-target species closely related to the pest. This lack of testing has been justified on the basis that there is little evidence that adverse effects have resulted from such introductions. An example of challenging a non-target species is that involving the use of the wasp *Apanteles erionotae*, a parasitoid of larvae of *Erionota thrax* the banana skipper, which recently appeared in Papua New Guinea. Tests have involved a relatively innocuous, closely related, palm skipper and two very distantly related Papua New Guinea birdwing butterflies.

5.26 A knowledge of the biology of the group to which the candidate agent belongs will often provide valuable information on its likely host specificity. Some groups of parasitoids are far more influenced in their selection of hosts by the characteristics of the environment in which the hosts are encountered than by any special characteristics of the host itself. For example, some species of *Trichogramma* wasps oviposit in almost any species of lepidopterous eggs encountered, some species of *Biosteres* wasp parasitise (or attempt to parasitise) the eggs or larvae of any fruit fly species they encounter in certain fruits, and various wood wasp parasitoids will oviposit in the larvae of any species of *Sirex* they locate in pine trees. Indeed this behaviour can be highly advantageous if some of the other hosts encountered in the target environment are also pests. It is, of course, prudent to consider such matters as whether a candidate parasitoid of, say, the eggs of a lepidopterous pest will also attack the eggs of a valuable introduced weed defoliator. However, as yet, there are few instances of introduced parasitoids significantly interfering with the biological control of weeds.

5.27 Increasing interest is being shown in certain groups of nematodes that attack insects exclusively and are completely harmless to other organisms. Some (such as a nematode that parasitises the *Sirex* wood wasp) are used as classical biological control agents, whereas others are mass reared and released at appropriate times to achieve control. These entomopathogenic nematodes actively seek out their hosts by reacting to carbon dioxide and other host metabolites. They show great promise for the control of certain tunneling and soil insects and should not be neglected as potential biological control agents in the Pacific.

Predators

5.28 Predators of insect and mite pests are generally far less specific than parasitoids. Those generally employed are coccinellid beetles and lacewings, although there are many predaceous bugs, flies and wasps. The predators that have achieved greatest success in biological control are the ladybirds or coccinellids. Although a few coccinellids appear to be either monophagous or oligophagous, the vast majority are polyphagous and attack a very wide range of insect hosts, principally scale insects or aphids (or both). They appear to be relatively inefficient in locating prey at lower densities and progressively lose interest in a prey species as it becomes scarce, turning their attention to more abundant species in the same locality. Coccinellid species that are shown by experimentation to be monophagous or oligophagous clearly merit serious consideration as biological control agents and it is desirable to study them before considering the importation of polyphagous species. Apart from considering possible effects on non-target species, there are other justifications for choosing more specific rather than less specific natural enemies.

Guideline 6. Safe Introduction of Biological Control Agents

6.1 Before a biological control agent is introduced into a country it is necessary to ensure that it has only a very narrow host range and will attack only the desired target pest or weed, or at least not produce undesired effects on non-target organisms. This is established by host specificity testing (Guideline 5). If these tests give acceptable results it is essential to ensure that no other organisms are introduced with the agent.

6.2 Apart from exceptional cases, the agent should be bred through one or more (but not too many) generations under secure quarantine in the importing country before release. This is to enable confirmation of the identity of the imported species and the elimination of any undesirable organisms, such as parasitoids, hyperparasitoids or disease organisms.

6.3 If there are no secure quarantine facilities or trained staff to service a breeding programme it is permissible to accept stocks bred for one or more generations in secure quarantine in another country. Under these circumstances, after presumed 'clean' material has arrived in the importing country, it is desirable for each individual living biological control agent to be carefully examined under a microscope before being cleared for release. This is often most easily done by placing each individual in a small capsule or tube, the transfer being carried out in a sleeved cage to prevent escape of living material. When eggs are imported they should be held until they have hatched, and when larvae or pupae are imported they should be bred through to adults. These activities should be carried out under such conditions that emerging parasitoids can be retained until they can be destroyed. Any diseased individuals should be preserved for later examination and, if there are many, the advice of an insect pathologist should be sought before any material is liberated. In certain cases great care must be taken not to introduce fungal infections (e.g. the devastating coffee rust) as unintended contaminants of biological control agents.

6.4 If any fellow travellers are detected, a careful review of the situation should be made by the importing authority before permitting the release of any material in the field, even after individual examination. Either the entire consignment should be destroyed or the species should be cultured for a generation in the laboratory under the most secure conditions available, examining each individual from this culture separately before field release, to make sure it is of the intended species and also healthy.

6.5 Voucher specimens of the biological control agent(s), and of any other organisms in the shipment, should be killed and pinned or preserved in alcohol, fully labelled and stored in-country. In addition, it would be highly desirable to lodge voucher specimens for safe-keeping in the New Zealand National Arthropod Collection, DSIR Plant Protection, Private Bag, Auckland, New Zealand which, for some years, has been building up a major reference collection of insects of importance in the southwest Pacific.

6.6 Except for healthy specimens of the agent species, all other imported material should be destroyed by (a) placing in a deep freeze overnight and later microwaving or burning; (b) immersing in alcohol or formalin; or (c) autoclaving.

6.7 It is extremely hazardous to make field collections of parasitoids or predators of a given pest, or of herbivorous insects attacking weeds, in one Pacific country and, without further processing as above, hand-carry or despatch these to another Pacific country for liberation in the field. The procedures outlined above must be followed to make sure serious mistakes do not occur. If, in spite of this strong discouragement, this procedure is proposed, skilled advice should be sought in each instance about how to minimise the risks involved.

6.8 Hosts of biological control agents accompanying them - whether plant material or invertebrates - should never be released.

6.9 If the foregoing conditions cannot be met, then the importing country should seek assistance from outside agencies in the region that have appropriate facilities and experienced personnel (e.g. the Division of Entomology of the Commonwealth Scientific and Industrial Research Organisation, Australia; Department of Scientific and Industrial Research Plant Protection, New Zealand; the Hawaiian Department of Agriculture; or the Plant Protection Service of the South Pacific Commission)

6.10 Prior written approval (letter or import permit) must always be obtained from the relevant authority of the receiving country before introducing a living organism intended for biological control. This authorisation will often specify the conditions under which an introduction can be made. In some countries separate authorisations are required, for introductions into quarantine and for permission to release.

DEVELOPMENT OF A BIOLOGICAL CONTROL DATA BASE

WILSON NG AND J. MCCONNELL

University of Guam,
College of Agriculture & Life Sciences, Mangilao, Guam 96923

ABSTRACT A biological control database was developed which contains information relating to identified pests in the American Pacific and their biological control agents. The data was obtained from surveys conducted by various entomologists. The data was set up in such a way that individuals can make inquiries as to the control of various pests or the success of various agents in controlling specific pests.

There are three main ways of looking at the information. First, there is a file of pests containing the Order, Family, Genus, Species, common name, site occurrences, and list of effective agents. The agent list contains the scientific name, common name, native origin, and a list of pests it is effective for. The release records contain the pest names, pest hosts, pest distribution, agent release site, and date of release.

A by-product of this projects was the development of dictionaries of agents and pests of the American Pacific. These dictionaries are usable in various spelling checkers found in work processing programs.

A computerized data base was developed which contains information relating to identify pests in the American Pacific and their biological control agents. The goal of developing this data was to compile all available information in the Region onto easily accessible form. The concept and data fields were developed based on inputs from Drs. Jack Beardsley, Don Nafus and Ilse Schreiner. The data was obtained from the same individuals. The data was set up in such a way that individuals can make inquiries as to the control of various pests or the success of various agents in controlling specific pests. The purpose of this presentation is to discuss the the design of the database, the user interface and demonstrate how to use the database. It should be noted that this project was developed into a 4-H project by the UOG 4-H Computer Club. The development of the database and the entry of data was done by members of the club.

This project went through a long preliminary stage of exploring various options as to how to set up the database. Orignally the database was developed in Oracle in MS-Dos format. This was found to be cumbersome and difficult to use. Because of this it was decided to first develop a version on the MacIntosh sysem. Various database designs were evaluated. Among the programs used were Hypercard, Double Helix II and 4 th Dimension. Afer evaluating the strengths and weaknesses of each, it was decided to continue development with 4th Dimension.

The database structure. A database was developed consisting of three databases linked in a relational manner: Pest, Agent and Release Records. By using a relational database, information that is used in many records would only have to be entered once and could be linked to multiple records. This was important in making data entry as easy as possible. Once the structure was developed, the data was entered to make a working version for further developemnt. Figure 1 displays the structure as created in 4th dimension.

The user interface. The user interface is considered one of the most important aspects of the project. Most of the development time has been devoted to the user interface. It was also desired to reduce as much as possible typing to avoid data entry errors. To approach this problem, it was decided to utilize the mouse. The mouse would be used to select choices in menus and also to select button icons. Figure 2 shows a sample screen of the Pest database. You may selct a series of records, generate reports, sort, create new records and modify exisiting records.

Accessing the databases. Creating and modifying database records has been streamlined to avoid data entry errors. The top of the screen (Figure 2) contains all pull-down menus needed for record navigation, manipulation, reporting, viewing related or linked records or other needed functions. Figure 3 displays an example of a pest entry screen. This layout allows the user to view, edit and add information for a pest or biological control agent. Users may add new biological agent release data through the use of the release records layout (Figure 4). Also included are "wildcard" fields where the user can type the first few letters of a biological control agent and the database will search for the closest match. If the database finds more than one matching name, it will present a list of biological control agents for your selection.
Improving the database. We have a variety of options to utilize due to the power and expandability of the 4th Dimension database. Various suggestions include scanning graphics of the biological control agent and pests, graphic maps of the five islands of ADAP (American Samoa, Guam, Hawaii, Pohnpei and Saipan) for data entry, report generation and compiling the database to a stand-alone application so that each site does not need a copy of 4th Dimension.

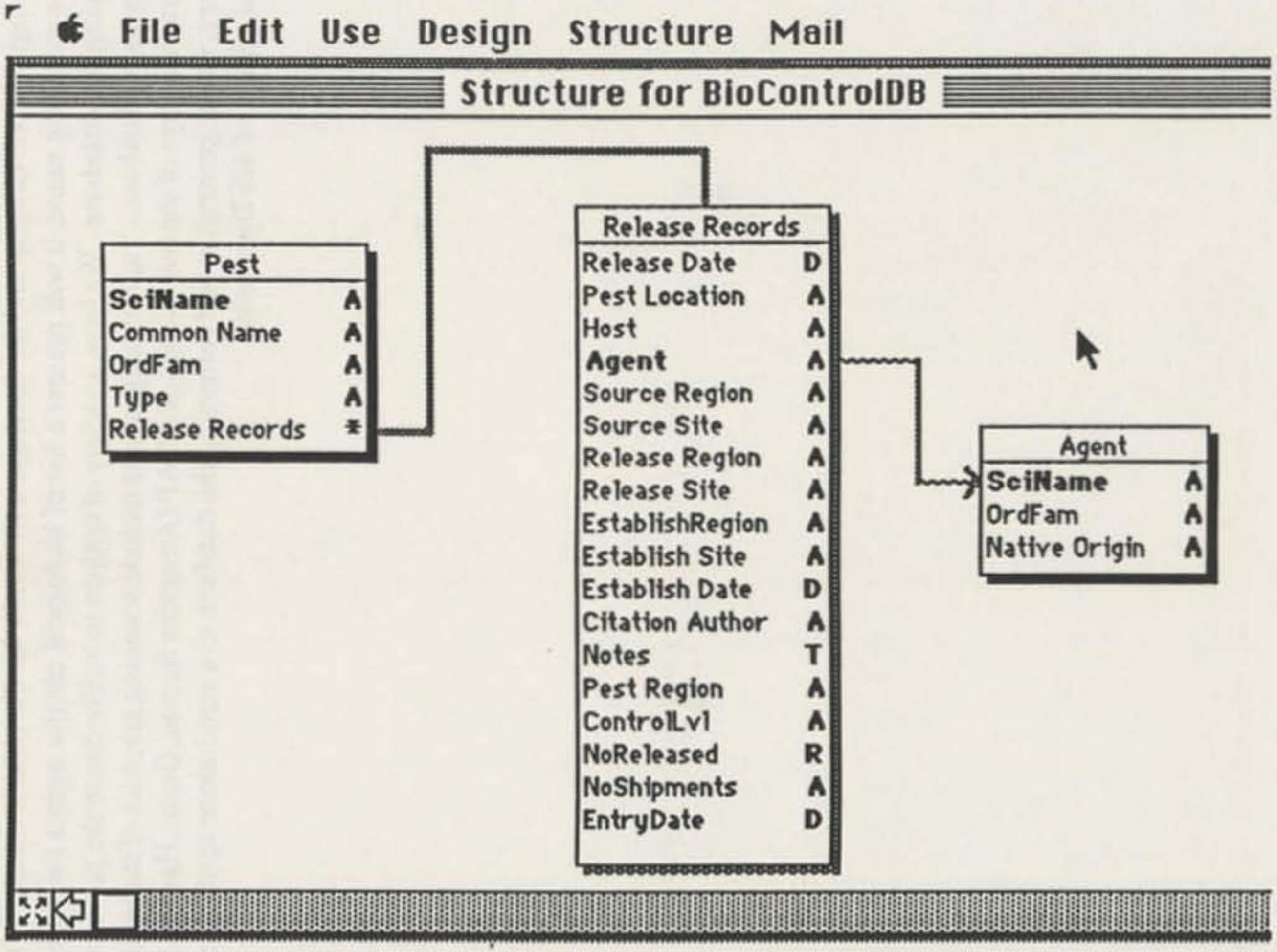

FIGURE 1. DATABASE STRUCTURE

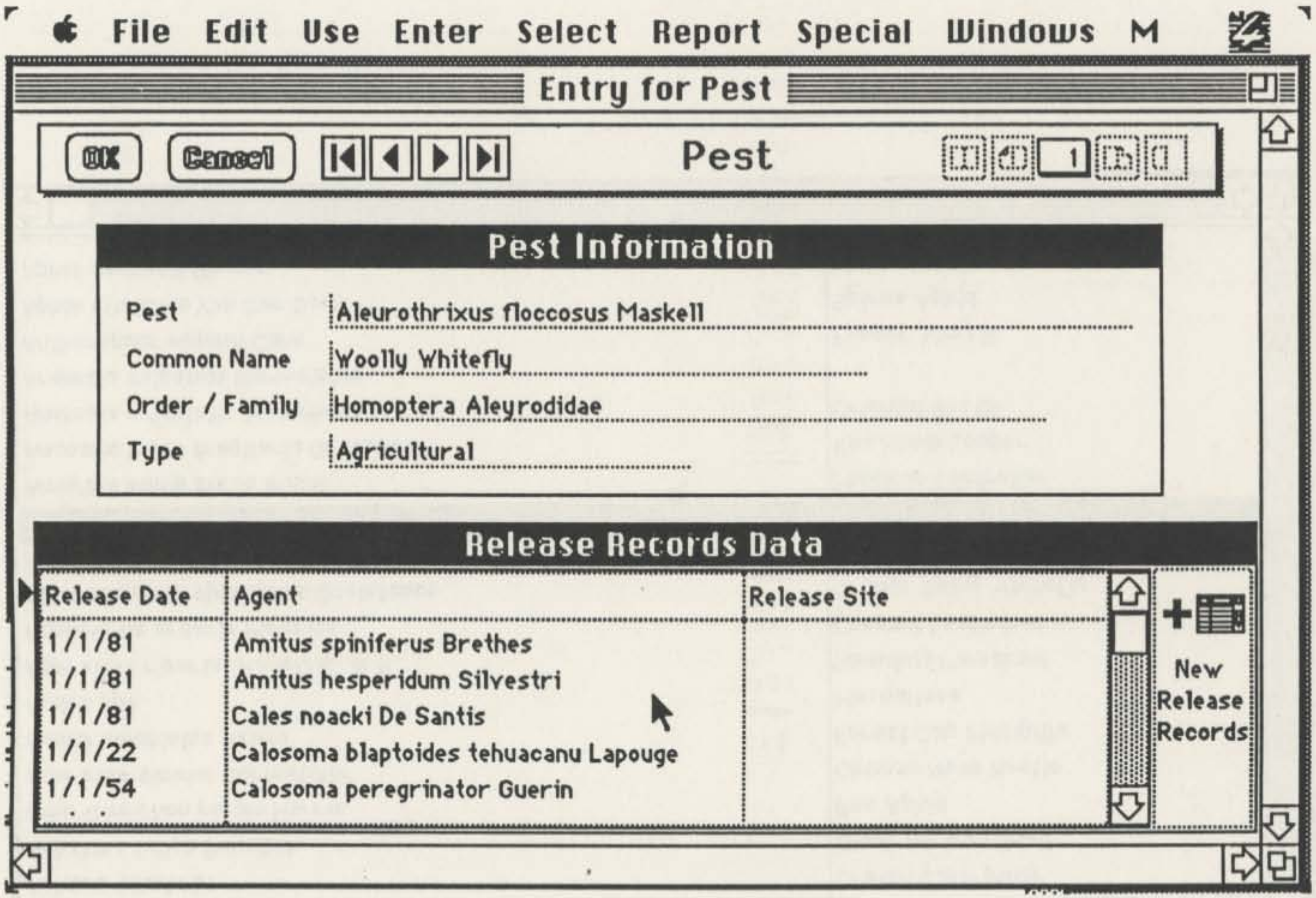

FIGURE 3. Pest Data Entry

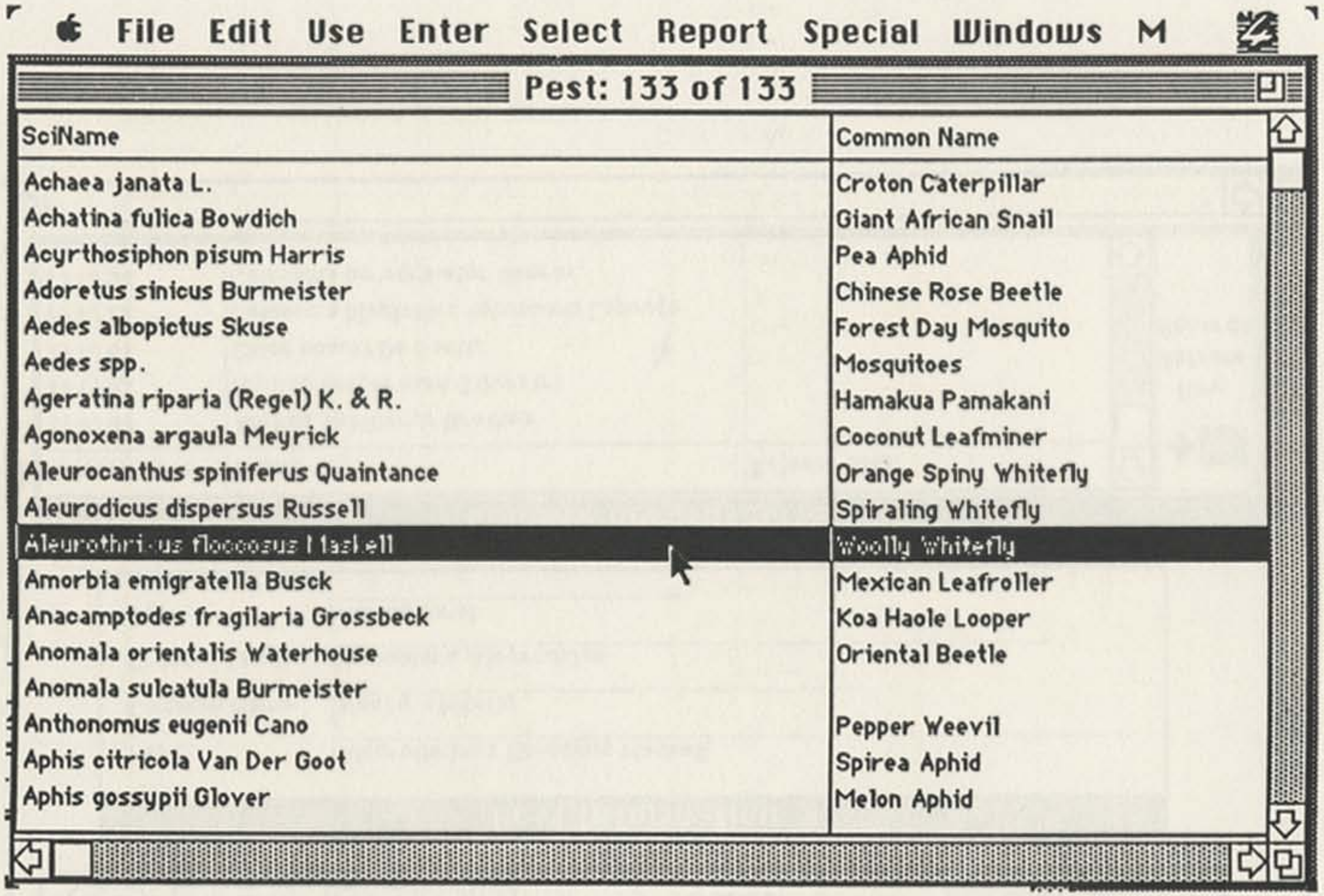

FIGURE 2. PEST DATABASE

ESTABLISHMENT OF *TELENOMUS* SP. (HYMENOPTERA: SCELIONIDAE) IN WESTERN SAMOA, FOR BIOLOGICAL CONTROL OF *OTHREIS FULLONIA* (CLERCK) (LEPIDOPTERA: NOCTUIDAE).

D.P.A. SANDS and W.J.M.M. LIEBREGTS

CSIRO, Division of Entomology, Private Bag No 3, Indooroopilly, Queensland 4068, Australia

ABSTRACT Surveys for natural enemies of the fruit piercing moth, *Othreis fullonia* (Clerck)(Lepidoptera: Noctuidae) undertaken in the western Pacific region, identified two undescribed parasitic Hymenoptera from Papua New Guinea. One, a *Telenomus* sp. (Scelionidae) was most abundant in egg masses while the other, an *Ooencyrtus* sp. (Encyrtidae) was abundant in single eggs of *O. fullonia*, contributing to its biological control.

In 1988, *Telenomus* sp. from Papua New Guinea was introduced into quarantine in Brisbane, Australia where host specificity was tested with eggs of six species of Catocalinae, related to *O. fullonia*. Only eggs of *O. fullonia* or of species closely related to the genus *Othreis* supported complete development of the parasitoid. Following satisfactory tests, *Telenomus* sp. was introduced and released in Western Samoa where it established on the islands of Upolu and Savaii, to complement egg parasitisation by the endemic *Ooencyrtus crassulus* Prinsloo and Annecke and *Trichogramma* sp. After establishment of *Telenomus* sp. in December 1988, parasitisation in egg masses increased from 44 to 63 % and in single eggs from 58 to 83 % for the period June - December 1989. For the same period, eclosion of larvae of *O. fullonia* decreased from 34 to 20 % in egg masses and in single eggs from 42 to 17 %.

The prospects for biological control of *O. fullonia* in Western Samoa are promising. *Telenomus* sp. is currently being assessed for introduction into other Pacific countries including Fiji, Tonga and American Samoa.

Fruit piercing moths (Noctuidae: Catocalinae) are pests in many subtropical and tropical countries including Africa, Southeast Asia, the Americas, Australia and the Pacific islands. In the Pacific region the most destructive species is *Othreis fullonia* (Clerck), followed in importance by the related *Eudocima salaminia* (Cramer) and other *Othreis* spp. Both sexes of adult moths pierce the skin of ripening fruit with their heavily sclerotized proboscis to feed on the juice (Sands and Schotz 1989). The larvae of these species are not considered to be pests since they feed on leaves of forest vines in the family Menispermaceae and also on coral trees (*Erythrina* spp.: Fabaceae) on the Pacific islands (Cochereau 1977).

Fruit piercing moths attack almost all kinds of fruit picked when close to ripening, particularly citrus, lychees, guavas, peaches, mangoes, paw paws, tomatoes and capsicums. Freshly pierced fruit, for example lychees, are sometimes overlooked when packed for market. The developing decomposition may spread to spoil other undamaged fruit in the containers (Sands and Schotz 1989). In Western Samoa *O. fullonia* is regarded as a particularly serious pest, preventing commercial production of citrus and several other fruit (unpubl.).

The natural enemies of fruit piercing moths are considered to be important in reducing abundance of the moths in some Pacific countries (Waterhouse and Norris 1987). For example, hymenopterous egg parasites *Ooencyrtus* sp. and *Telenomus* sp., and the dipterous larval parasite *Winthemia caledoniae* Mesnil, are reported to contribute to control of *O. fullonia* in New Caledonia (Cochereau 1974, 1977). Surveys in the western Pacific located a range of natural enemies including some unidentified egg parasitoids that were considered potential biological control agents for *O. fullonia* (Sands and Broe 1991). In Papua New Guinea, egg parasitoids of *O. fullonia* are abundant (Sands and Liebregts 1988) and thought to contribute to the

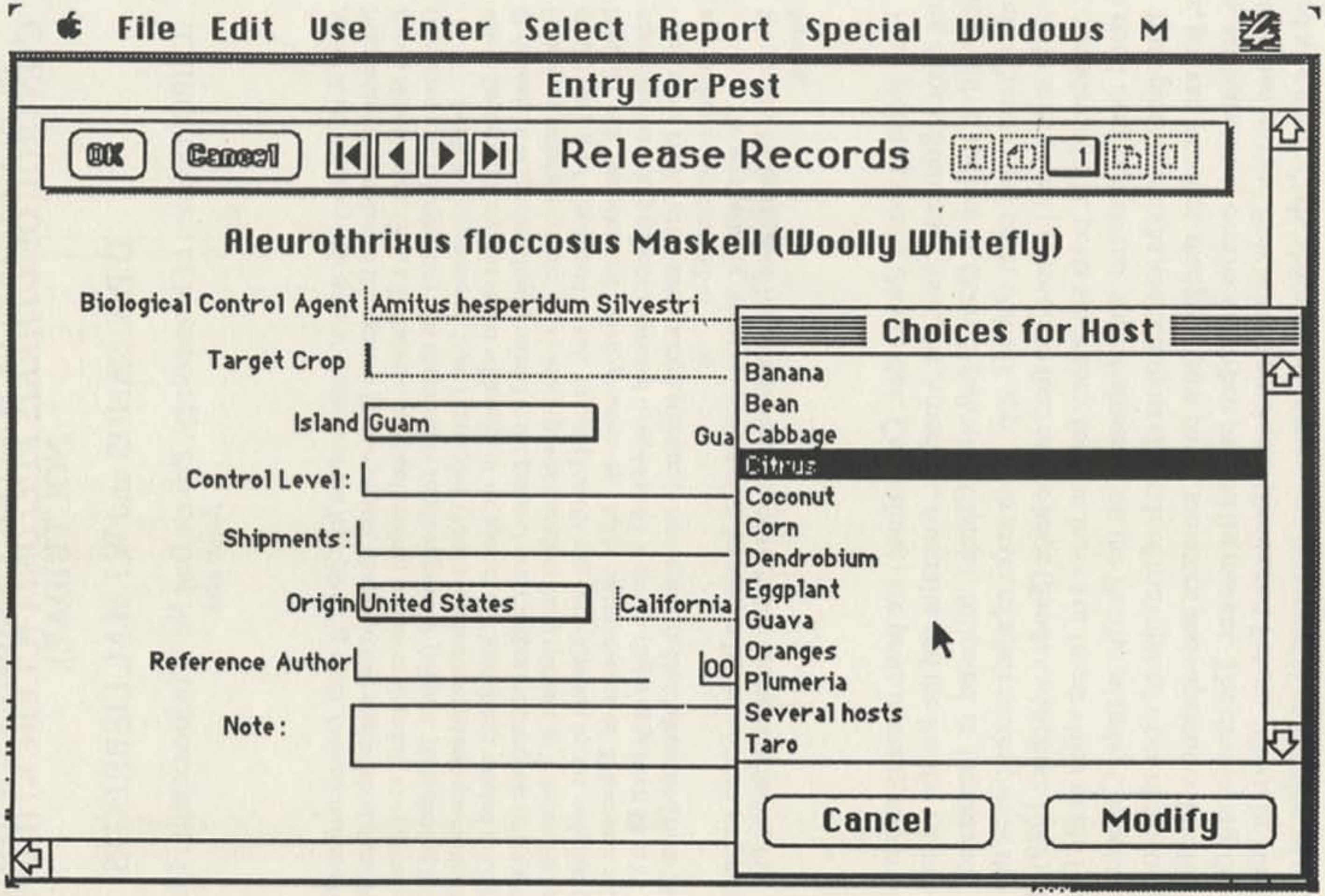

FIGURE 4. Release Data Entry

relatively low abundance of the moth and its unimportance as a pest in that country (Sands and Broe 1991).

We discuss the evaluation of an undescribed *Telenomus* sp. from Papua New Guinea, its introduction and establishment in Western Samoa for biological control of *O. fullonia.*

Materials and Methods

Single eggs and egg masses (> 3 eggs in a group) of *O. fullonia* were collected from leaves of *Erythrina variegata* L., near Madang (5°14'S, 145°45'E) and between Siar Plantation and Malolo, Madang Province, Papua New Guinea (PNG). These were maintained in an air conditioned laboratory at *ca* 25°C in plastic tubes measuring 95 x 10 mm, plugged with cotton wool until moth larvae or parasitoids emerged. Eclosing larvae were removed from the tubes and honey streaked on wax paper was introduced as food for the emerging parasitoids.

Parasitised eggs were consigned to Brisbane, Australia where they were held in a quarantine facility at the CSIRO, Long Pocket Laboratories until parasitoids emerged. *Telenomus* sp. and *Ooencyrtus* sp. were separated and a culture of *Telenomus* sp. (Ref. No. LPL530) was established using as hosts, eggs of Australian fruit piercing moths. The quarantine insectary was air conditioned to 25°C $\pm$0.5°C, RH *ca*, 70%.

Tests for host specificity of *Telenomus* sp. were made by exposing eggs of six species of moths related to *O. fullonia* (Catocalinae) for 24 hours in no-choice tests. Eggs were held at 25°C until larvae or parasitoids emerged, or for 21 days if no eclosion occurred. Following tests for specificity, a culture of *Telenomus* sp. was transferred to a sub-quarantine unit in Western Samoa for rearing on eggs of local *O. fullonia*. Parasitoids were reared for one generation to confirm the identity of *Telenomus* sp. before rearing for release.

Prior to liberation of *Telenomus* sp. in Western Samoa, levels of endemic parasitoids (*Ooencyrtus crassulus* and *Trichogramma* sp.) were monitored at the island Savaii from single eggs and egg masses containing developing moth larvae or parasitoids. Eggs were held at ambient temperatures in glass tubes until larvae or parasitoids emerged.

Percentages for larvae of *O. fullonia* eclosed, eggs with each parasite species and other mortality were averaged from each egg mass and from single eggs for each collection date. Mortality data for egg masses were calculated separately.

Results

Surveys in Papua New Guinea. The data for parasitisation of egg masses (Table 1) and for single eggs (Table 2) of *O. fullonia* from PNG are contrasted with data from Western Samoa. In PNG the predominant parasitoid in egg masses was *Telenomus* sp. while in single eggs it was an *Ooencyrtus* sp. Since most eggs in Western Samoa are deposited in masses, a decision was made to first introduce and establish the most effective parasitoid species in egg masses of *O. fullonia* from PNG.

Hosts accepted for development by *Telenomus* sp.. The acceptability of eggs of species of Catocalinae as hosts for *Telenomus* sp. are shown in Table 3. Only *O. fullonia* or species in genera closely related to *Othreis* spp. were suitable for development by *Telenomus* sp., indicating a high degree of host specificity.

Establishment of *Telenomus* sp. in Western Samoa. From October 1988 - August 1989, a total of 6,415 (2,742 on Savaii, 3,673 on Upolu) *Telenomus* sp. were released in breeding areas for *O. fullonia* in Western Samoa. The first field recovery of *Telenomus* sp. was made in December 1988 near a release site on Savaii. Except for a period of 3 months following cyclone "Ofa" in February 1990, *Telenomus* sp. was recovered from all release sites and at locations more than 3 km from the release sites on Savaii on all sampling occasions.

Table 1. Natural mortality in egg masses of *O. fullonia* from Papua New Guinea and Western Samoa

	masses				eggs in masses			
	Papua New Guinea		Western Samoa		Papua New Guinea		Western Samoa	
Dates*	1987	1988	1988	1989	1987	1988	1988	1989
No. masses collected	26	48	105	177				
% masses with:								
larvae eclosed	39.6	32.5	39.0	37.3	22.7	14.1	34.0	20.3
parasitised by:								
Ooencyrtus sp.	19.2	61.1	.	.	16.6	17.7	.	.
O. crassulus	0	0	79.0	77.4	0	0	43.7	37.0
Telenomus sp.	88.5	77.8	0	47.5	47.9	49.9	0	25.6
Trichogramma	.	.	1.0	0	.	.	0.6	0
Total parasitised	100.0	94.4	79.0	89.3	64.5	67.6	44.3	62.6
Other mortality	30.8	67.7	67.6	53.7	12.8	18.3	21.8	17.0

Collection dates: PNG: 13.vii-4.viii 1987, 4.vii-24.vii 1988; WS: i-xi 1988 before, and vi-xii 1989 after establishment of *Telenomus* sp.

Table 2. Natural mortality in single eggs of *Othreis fullonia* from Papua New Guinea and Western Samoa

	Papua New Guinea		Western Samoa	
	1987	1988	1988	1989
No. eggs collected	33	25	137	399
% with[1]:				
larvae eclosed	30.3	4.0	41.9	17.1
parasitised by:				
Ooencyrtus sp.	69.7	72.0	.	.
O. crassulus	0	0	58.1	66.6
Telenomus sp.	0	24.0	0	16.4
total parasitised	69.7	96.0	58.1	83.0

[1] Percentages are means of data from each date of collection

Table 3. **Host suitabliity of eggs of Catocalinae (Noctuidae) for development by *Telenomus* sp.**

Species of Catocalinae	No. eggs: Exposed	Unparasitised	Supported devel. of *Telenomus*
Othreis fullonia (Clerck)	48	2	46
Eudocima salaminia (Cramer)	310	90	220
Anomus sp.	2	2	0
Donuca rubropicta (Butler)	5	3	0
Erebus terminitincta Fletcher	5	5	0
Ophiusa disjungens (Walker)	5	5	0
Parallelia redunca (Swinhoe)	5	5	0

Data from egg masses and single eggs collected prior to liberation of *Telenomus* sp. in 1988, are contrasted with data for the period June - December 1989 (Tables 1 & 2). While the levels of egg parasitisation by endemic species decreased slightly after the establishment of *Telenomus* sp., in Western Samoa, total eggs parasitised increased in egg masses by 18.3 % and the eclosion of larvae of *O. fullonia* from eggs decreased by 13.7%. During the same period, parasitisation in single eggs increased by 24.9% while eclosion of larvae decreased by 24.8%. When data from the two periods were compared, there were no significant differences in the number of egg masses attacked by endemic parasitoids or in masses yielding larvae of *O. fullonia* following establishment of *Telenomus* sp.

Discussion

The natural enemies of *O. fullonia* are considered to contribute to biological control of the moth in the Pacific region (Waterhouse and Norris 1987). For example, the tachinid fly, *Winthemia caledoniae* and an egg parasitoid *Ooencyrtus* sp., are said to reduce the abundance of *O. fullonia* in New Caledonia (Cochereau 1977). However, *W. caledoniae* failed to establish in Fiji despite liberations made over several years (S.N. Lal pers. comm.). Despite activity of endemic natural enemies in Western Samoa (Sands and Broe 1991), *O. fullonia* continues to be a major pest of fruit on the islands of Upolu and Savaii. Studies carried out at experimental orchards have shown that damage is always severe, with total losses occurring in outbreak years (unpubl. data). This level of damage to citrus is probably more severe than recorded from most other western Pacific countries, except in outbreak years. Serious damage occurs occasionally in New Caledonia (Cochereau 1977), Fiji (Kumar and Lal 1983), American Samoa (Comstock 1963) and Vanuatu (R. Weller pers. comm.) but less damage (e.g. 10 - 15% in Fiji, Kumar and Lal 1983) occurred at most other times.

Several species of *Telenomus* are recognised as important biological control agents for lepidopterous (Polaszek and Kimani 1990) and other insect pests (Bin and Johnson 1982). The decision to introduce a *Telenomus* sp. into Western Samoa was based on absence of this genus parasitising *O. fullonia* in Western Samoa and the activity of this parasitoid in Papua New Guinea (Sands and Broe 1991). Following establishment of *Telenomus* sp. in Western Samoa, levels of parasitisation in single eggs and egg masses increased and were accompanied by decreases in the eclosion of moth larvae. It remains to be seen whether these levels are sustained and whether they contribute to lowered abundance of adult *O. fullonia* in Western Samoa.

In a collaborative program, CSIRO Australia and the Department of Agriculture, Forests and Fisheries, Western Samoa are evaluating the most promising agents for biological control of *O. fullonia*. If effective in Western Samoa, these agents including *Telenomus* sp. from Papua New Guinea, will be considered for introduction to other Pacific countries including Fiji, Tonga, American Samoa and Australia, where *O. fullonia* remains one of the most serious pests of tropical fruit.

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THE DISTRIBUTION AND BIOLOGICAL CONTROL OF THE FRUIT-PIERCING MOTH, *OTHREIS FULLONIA* (LEPIDOPTERA: NOCTUIDAE) IN MICRONESIA

G.R.W. DENTON, R. MUNIAPPAN[1], M. MARUTANI, T.S. LALI, L. CRUZ, D. AFAISEN, S. MEYER, C.-H. CHIU[2] AND N. ESGUERRA[3]

Agriculture Experiment Station, College of Agriculture and Life Science, UOG Station, University of Guam, Mangilao,Guam 96923, U.S.A

ABSTRACT The fruit-piercing moth *Othreis fullonia* is widespread throughout the Indo-Pacific although its distribution and impact within Micronesia remains to be documented. For these reasons, surveys were undertaken to establish the presence, pest status and natural enemies of this species within the Caroline and Mariana Island groups. Inter-island differences were encountered for all three parameters. In addition, a number of other fruit-piercing species were identified and their impact evaluated.

The fruit-piercing moth *Othreis fullonia* (Clerck) is widespread throughout the Indo-Pacific region. The adult moth feeds on the pulp and juice of a variety of fruits, which it pierces with its heavily armored proboscis. As a consequence, it is a serious pest throughout much of its range.

In their native habitat, the larvae of *O. fullonia* feed on vines of the family Menispermaceae, a group of plants which are absent on most Pacific Islands. However, their successful adaption to species of *Erythrina*, a completely unrelated taxonomic group (Fabaceae) widely spread throughout the Pacific, coupled with the adult moth's remarkable ability for sustained flight, has permitted their successful introduction and establishment into this region.

At the University of Guam, a collaborative ADAP funded study is underway to investigate the biology, distribution and natural enemies of *O. fullonia* in Micronesia. Details of the life cycle, food preferences, pest status and natural enemies of *O. fullonia* from Guam, have previously been reported (Denton *et al.* in press). This paper presents new data from Guam and discusses the importance and biological control of the species on other Micronesian islands. Details about other fruit-piercing moth species collected during the course of this work are also included.

Methods and Materials

Brief 1-2 day surveys, to establish the existence and local importance of *O. fullonia*, were conducted in Belau (Koror and adjacent States) and Yap in the Western Caroline Islands; on Pohnpei and Chuuk (Moen) in the Eastern Caroline Islands; and Rota, Tinian and Saipan in the archipelago of the Marianas (Figure 1) between September 1988 and December 1989. Where possible, *O. fullonia* eggs were collected from local *Erythrina* trees to assess the degree of egg parasitism and impact of other natural enemies on egg development. Searches for feeding adult *O. fullonia* and other fruit piercing species were made at night when conditions permitted.

[1]To whom all correpsondence should be addressed

[2]Northern Marianas College, Cooperative State Service, P.O. Box 1250, Saipan, MP 96950

[3]College of Micronesia, Agriculture Experiment Station, P.O. Box 1179, Kolonia, Pohnpei FM 96941

In Guam, studies to assess seasonal changes in abundance of eggs and the egg parasitoids of *O. fullonia* commenced in March 1989 and are on-going. Eggs are collected from established *Erythrina* trees from six sites widely distributed over the island (Figure 1). Each collection is made over a standardized 30 minute time interval to facilitate both spatial and temporal comparisons between data sets.

Results and Discussion

Distribution and Pest Status. The distribution and pest status of *O. fullonia* in the islands visited are summarized in Table 1. The information for Kosrae stems from an earlier visit by one of us (R.M). The abundance and relative importance of *O. fullonia* varies significantly between islands. In the western Carolines, for example, the species is present in Belau but absent from Yap, and in the eastern Carolines, it is found in Pohnpei but not Chuuk.

In Belau, specimens collected by the Biological Laboratory date back to 1952 (Otobed, pers. comm.). However, the moth has never been a problem here; a fact which was substantiated during the present survey by the very low incidence of fruit attack observed locally.

O. fullonia is very common in Guam, where the earliest reported sightings date back to 1936 (Swezey 1946). In 1985, the moth was officially listed among Guam's top ten invertebrate pests (Waterhouse and Norris 1987). Several different types of locally grown fruits are known to be attacked by this species, especially the sweeter, more aromatic varieties such as ripe banana, guava, papaya and carambola (Denton et al. in press). Previous observations based on larval activity suggested that populations of *O. fullonia* undergo distinct seasonal fluctuations in Guam, with highest numbers occurring during the wet season. Our recent findings, based on biweekly collections of eggs from the field, provide further evidence for this (Figure 2).

O. fullonia was abundant and of local concern on most other Mariana islands visited. It was a particularly troublesome pest in Tinian, where it had inflicted considerable damage to commercial guava plantations in the north of the island. This undoubtedly would have resulted in considerable financial loss to the company (Bio-Pacific).

It seems likely that the development of commercial mango and papaya plantations, currently underway in the south of Guam, may suffer a similar fate unless adequate control methods are implemented to ensure otherwise.

Relatively large numbers of *O. fullonia* were found at Pohnpei, although the current absence of a major fruit export industry means the species does not cause the same degree of economic loss as experienced by citrus farmers in the neighboring island of Kosrae (Muniappan, unpubl. data). Nevertheless, its impact on citrus and soft fruits grown for local consumption in Pohnpei was clearly apparent.

The absence of O. *fullonia* from Yap and Chuuk is of interest and does not appear to be related to host plant availability. Indeed, several large *Erythrina* trees were located on each island, and would have provided ample food for the developing larvae. In both cases, however, neither eggs nor larvae were found despite exhaustive searches. Similarly, all local fruits examined revealed no evidence of fruit-piercing moth attack. Quite possibly, the species has yet to arrive.

Biological Control. Although there are several known natural enemies of *O. fullonia* (Waterhouse and Norris 1987), the egg parasitoid wasps, particularly those of the genera *Telenomus*, *Ooencyrtus* and *Trichogramma*, rank among the most successful biological control agents. Emphasis was therefore given to establishing their presence and effectiveness on Guam and the other Micronesian islands visited.

In Belau, these objectives fell short as a result of our failure to locate eggs of *O. fullonia* from the many *Erythrina* trees examined. An explanation for this may be that eggs are laid on different host plants there. At least one member of the Menispermaceae , *Pachyzon ledermannii* , is known to grow in Belau (Otobed pers. comm.) and is an obvious candidate for further investigations in this regard.

In Guam, all three genera of wasps are present, although *Telenomus* is generally the dominant egg parasitoid closely followed by *Ooencyrtus*. In contrast, *Trichogramma* plays a relatively minor role in controlling fruit-piercing moth populations (Table 2).

In addition to the above, at least seven other species of micro-hymenoptera have so far been collected from Guam. However, their occurrence is rare and collectively they account for <0.1% of the total number of eggs parasitized. Two of these wasps, *Cheiloneurus* sp. (Encyrtidae) and *Marietta* sp. (Aphelinidae), are known hyperparasites of *Trichogramma*. The remaining wasps await identification.

Our seasonal studies indicate that changes in the abundance of *Telenomus* and *Ooencyrtus* (Figure 3) mirror changes in host availability; the net result being that parasitization rates generally remain the same throughout the year, i.e 60-80% for single eggs and 80-90% for egg clusters. Significant departures from this were occasionally encountered in *O. fullonia* eggs laid on the first flush of new growth after leaf fall and, presumably, reflected a period of recovery and/or re-establishment for the egg parasitoids. It should be mentioned here, however, that not all *Erythrina* trees loose their leaves at the same time and hence such departures tend to be diluted out when considering the island as a whole.

Another point of interest which emerges from the seasonal study is that, relative to *Telenomus*, *Ooencyrtus* parasitizes more single eggs during the wet season than it does during the dry season (Figure 3). This ties in with work of Cochereau (1972) who found that *Ooencyrtus* sp. from New Caladonia were more susceptible to dry conditions than either *Telenomus* or *Trichogramma*.

The egg parasitoid data from the other islands are summarized in Tables 3-6 and reveal several important points despite the relatively small sample sizes. For example, *Telenomus, Ooencyrtus* and *Trichogramma* are also found in Rota, Tinian and Saipan and show a similar rank order of effectiveness to that in Guam. In contrast, *Trichogramma* is the dominant egg parasitoid in Pohnpei while *Telenomus* plays a relatively insignificant role and *Ooencyrtus*, is not present.

Clear morphological differences were apparent between *Oencyrtus* collected from Guam and Rota compared with those from Tinian and Saipan. Also, *Telenomus* from Pohnpei was distinctly different from specimens observed elsewhere in the study. Investigations to identify other intra-specific differences are in progress.

Of particular interest, is the high incidence of bug attack encountered in both Rota and Tinian. This is most unusual and greatly exceeds anything witnessed on any of the other islands or reported in the literature. From Table 3, it is clear that these predators do not distinguish between parasitized and unparasitized eggs. Further studies are clearly warranted to identify and properly evaluate these insects as a potential bio-control agent.

In Guam, it would seem that less than 5% of the total number of eggs laid by *O. fullonia* actually produce viable larvae (Table 2). Additional samples, collected over extended periods of time, are required from the other islands before comparable values can be predicted with any degree of confidence. The data from Tinian best highlights this need, because virtually all of the egg masses collected were from *Erythrina* trees along the southern foreshore of the island, and, at the time of collection, the prevailing onshore winds were clearly a key factor in preventing micro-hymenopteran migration from the island interior.

Related Fruit-Piercing Species. Several other fruit-piercing species have been discovered in this study (Table 7). All are Noctuids and none are currently of the same pest status as *O. fullonia*. They have been classified as either "primary" or "secondary" fruit- piercing species according to their ability to pierce fruit, which, in turn, largely reflects the degree of sclerotization and armature of the proboscis (Banziger 1982).

For the purpose of this discussion, primary fruit-piercers are regarded as those capable of penetrating the skin and pulp of a wide variety of fruits including citrus. Secondary fruit-piercers, on the other hand, are generally unable to penetrate the skin of all but the softest fruits and use existing holes and other breaks in the skin to reach the pulp beneath.

The primary fruit-piercing moths, *Platyja umminia* and *Ercheia dubia* are recent introductions to Guam and were first noted in 1988 and 1989 respectively. They are relatively common on the island at certain times of the year, although we currently know little of their biology and their larval host plants remain to be discovered. Our preliminary field observations suggest that both species have the potential to become major pests of fruit crops grown on the island.

Both species possess a heavily sclerotized, spear-like proboscis the edges of which are smooth and sharp in *P. umminia* and serrated in *E. dubia*. Both lack the barbs, hooks and spines which characterize the proboscis of *O. fullonia*.

The distribution of *P. umminia* within Micronesia appears to be confined to Guam at the present time, whereas *E. dubia* is widely distributed throughout the Marianas and possible beyond. *P. umminia* and three related species of *Ercheia* have previously been reported as a primary fruit- piercing species in Thailand (Banziger 1982).

The fourth species of primary fruit-piercing moth found in Guam, *Pericyma cruegeri*, has been on the island for many years and is perhaps better known for its larval defoliation of local flame trees. The impact of this species to local fruit growers is highly seasonal and comparatively short- lived with highest numbers occurring during September and October. The species is also found in Rota and Belau where it is not considered to be a major pest of fruit crops. Its proboscis is heavily armed with tearing hooks and stout bristles rendering tough skinned fruits like citrus and pomegranate susceptible to its attack.

All other species listed in Table 7 are classified as secondary fruit-piercing moths on the basis that their mouth parts are only lightly sclerotized. In certain species the proboscis tip is spatulate with numerous hair-like projections whilst in others it remains relatively undifferentiated with only a few rudimentary hairs along the shaft length.

Concluding Remarks

There is tremendous potential for economic development of tropical fruit production throughout the American Pacific. Cultivation of fruit crops as commercial commodities could be an economically feasible venture to those individuals and companies willing to pursue it. However, the presence of fruit piercing moths throughout this region is one of the hinderances of this type of development.

At the present time, *O. fullonia* is the most troublesome species of fruit-piercing moth within Micronesia and is of local importance on several islands. Despite the presence of several effective natural enemies in this region, damage to fruits may be particularly heavy at certain times of the year.

The egg parasitizing micro-hymenoptera currently rank among the most effective bio-control agent of this species in Micronesia, although various egg predators, e.g. ants and bugs, undoubtedly play a significant role in this respect.

The prospect of introducing additional natural enemies into Micronesia is being pursued. One high ranking candidate is a species of *Ooencyrtus* from New Guinea where it is known to be particularly effective in controlling *O. fullonia* populations. However, we feel the larval parasites merit the strongest consideration since none are currently found in Micronesia and some, e.g. *Winthemia caledoniae* (Diptera: Tachinidae) and certain species of *Euplectrus* (Hymenoptera: Eulophidae), have yielded encouraging results in some other parts of the world (Waterhouse and Norris 1987).

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Table 1. The Status of *Othreis fullonia* in Micronesia.

Island	Status
Western Caroline Islands	
Belau	+
Yap	A
Eastern Caroline Islands	
Pohnpei	++
Chuuk	A
Kosrae	+++
Archipelago of the Marianas	
Guam	+++
Rota	++
Aguijan	++
Tinian	+++
Saipan	+++

+++ = Very common and of local importance.
++ = Relatively common but locally unimportant.
\+ = Relatively uncommon and of no importance.
A = Absent.

Table 2. Condition of *Othreis fullonia* Eggs Collected from Guam.

Condition	Single Eggs	Egg Masses
	(%)	(%)
Non-parasitized	29.3	16.7
Hatched	3.5	3.3
Dead	0.1	0.2
Infertile/undeveloped	19.7	7.5
Attacked by fungi	2.0	3.9
Attacked by predatory bug	4.0	1.8
Parasitized	70.7	83.3
Telenomus sp.	45.3	52.2
Ooencyrtus sp.	15.0	21.8
Trichogramma sp.	1.6	0.2
Unidentified sp.	<0.1	<0.1
Dead	8.8	9.1

Island-wide compilation of data (from six sites) for eggs (3926 single eggs and 9672 eggs from 445 egg masses) collected from established *Erythrina* trees from March 1989 to March 1990. All eggs that had emerged at the time of collection were discarded. All data expressed as a percentage (%) of the total number of eggs collected.

Table 3. Condition of *Othreis fullonia* Eggs Collected from Rota.

Condition	Single Eggs	Egg Masses
	(%)	(%)
Non-parasitized	69.6	27.1
Hatched	2.9	0.0
Dead	0.0	0.0
Infertile/undeveloped	15.9	1.1
Attacked by fungi	2.9	0.0
Attacked by predatory bug	40.6	25.2
Attacked by chewing insect	0.0	0.8
Parasitized	31.9	72.9
Telenomus sp.	27.5	52.2
Ooencyrtus sp.	1.4	3.4
Trichogramma sp.	1.4	0.0
Unidentified sp.	0.0	0.0
Dead	1.4	17.3*

Compilation of data from eggs (69 single eggs and 266 eggs from 22 egg masses) laid on the leaves of established *Erythrina* trees (2-3 m above ground level) from the southern and southwestern portions of the island, September 26-27, 1989. All eggs that had emerged at the time of collection were not included. All data expressed as a percentage (%) of the total number of eggs collected.

*16.9% of dead parasitized eggs were killed by predatory bug attack.

Table 4. Condition of *Othreis fullonia* Eggs Collected from Tinian.

Condition	Single Eggs	Egg Masses
	(%)	(%)
Non-parasitized	66.3	87.8
Hatched	7.9	45.8
Dead	1.1	0.0
Infertile/undeveloped	13.5	3.3
Attacked by fungi	0.0	0.0
Attacked by predatory bug	43.8	38.7
Parasitized	33.7	12.2
Telenomus sp.	7.9	11.0
Ooencyrtus sp.	14.6	1.2
Trichogramma sp.	3.3	0.0
Unidentified sp.	0.0	0.0
Dead	7.9	0.0

Compilation of island-wide data from eggs (89 single eggs and 336 eggs from 21 egg masses) laid on the leaves of established *Erythrina* trees October 15-16, 1989. All eggs that had emerged at the time of collection were not included. All data expressed as a percentage (%) of the total number of eggs collected.

Table 5. Condition of *Othreis fullonia* Eggs Collected from Saipan.

Condition	Single Eggs	Egg Masses
	(%)	(%)
Non-parasitized	47.5	28.8
Hatched	13.1	23.0
Dead	0.0	0.0
Infertile/undeveloped	27.9	5.8
Attacked by fungi	6.5	0.0
Attacked by predatory bug	0.0	0.0
Parasitized	52.5	71.2
Telenomus sp.	34.4	55.8
Ooencyrtus sp.	16.4	15.4
Trichogramma sp.	1.7	0.0
Unidentified sp.	0.0	0.0
Dead	0.0	0.0

Compilation of data from eggs (61 single eggs and 52 eggs from 8 egg masses) laid on the leaves of established *Erythrina* trees (2-5 m above ground level) in the Kagman area September 25, 1989. All eggs that had emerged at the time of collection were not included. All data expressed as a percentage (%) of the total number of eggs collected.

Table 7. Fruit-Piercing Moths From Micronesia.

Species	Fruit-Piercing Status	Island[y]
Ercheia dubia (Butl.)	Primary	G, R, T, S
Othreis fullonia (Clerk)	Primary	G, R, T, S, B, P
Pericyma cruegeri (Butl.)	Primary	G, R, B
Platyja umminia (Cram.)	Primary	G
Achaea janata (L.)	Secondary	G, R, T, S, B, P
Achaea serva (Fabr.)	Secondary	G, T, B
Anomis flava (Fabr.)	Secondary	G, R, T, S, B, P
Anua coronata (Fabr.)	Secondary	G, T,
Anua tongaensis Hampson	Secondary	G, T
Dysgonia absentimaculal (Guen.)	Secondary	G
Ericeia inangulata (Guen.)	Secondary[z]	G, T, P
Grammodes geometrica (Fabr.)	Secondary[z]	G, T, S
Hulodes caranea (Cram.)	Secondary[z]	G, T, B
Mocis frugalis (Fabr.)	Secondary[z]	G, T, S, B, P
Mocis undata (Fabr.)	Secondary[z]	G, T, B, P
Parallelia palumba (Guen.)	Secondary	G
Platysenta illecta (Wlk.)	Secondary[z]	G, T
Polydesma boarmoides Guen.	Secondary[z]	G, T, P
Sericia sp	Secondary[z]	G, B
Thyas regia (Lucas)	Secondary	G, R, T, S, P

[z] Proboscis relatively simple and undifferentiated.
[y] G = Guam, R = Rota, T = Tinian, S = Saipan, B = Belau, and P = Pohnpei.

Figure 1. Sites where fruit piercing moth eggs were collected.

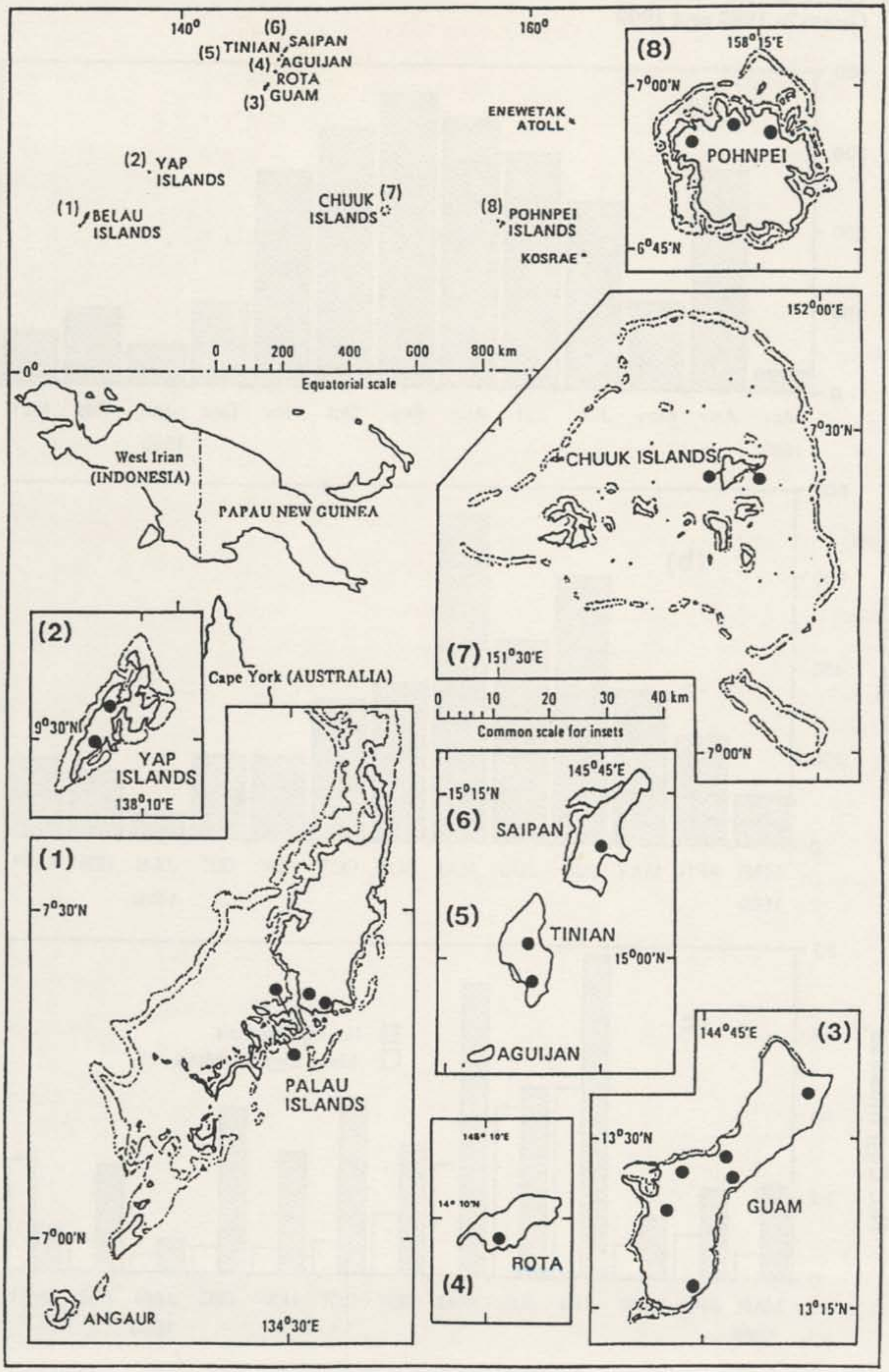


Figure 2. Monthly rainfall and number of fruit piercing/moth of eggs collected in Guam in 1989 and 1990

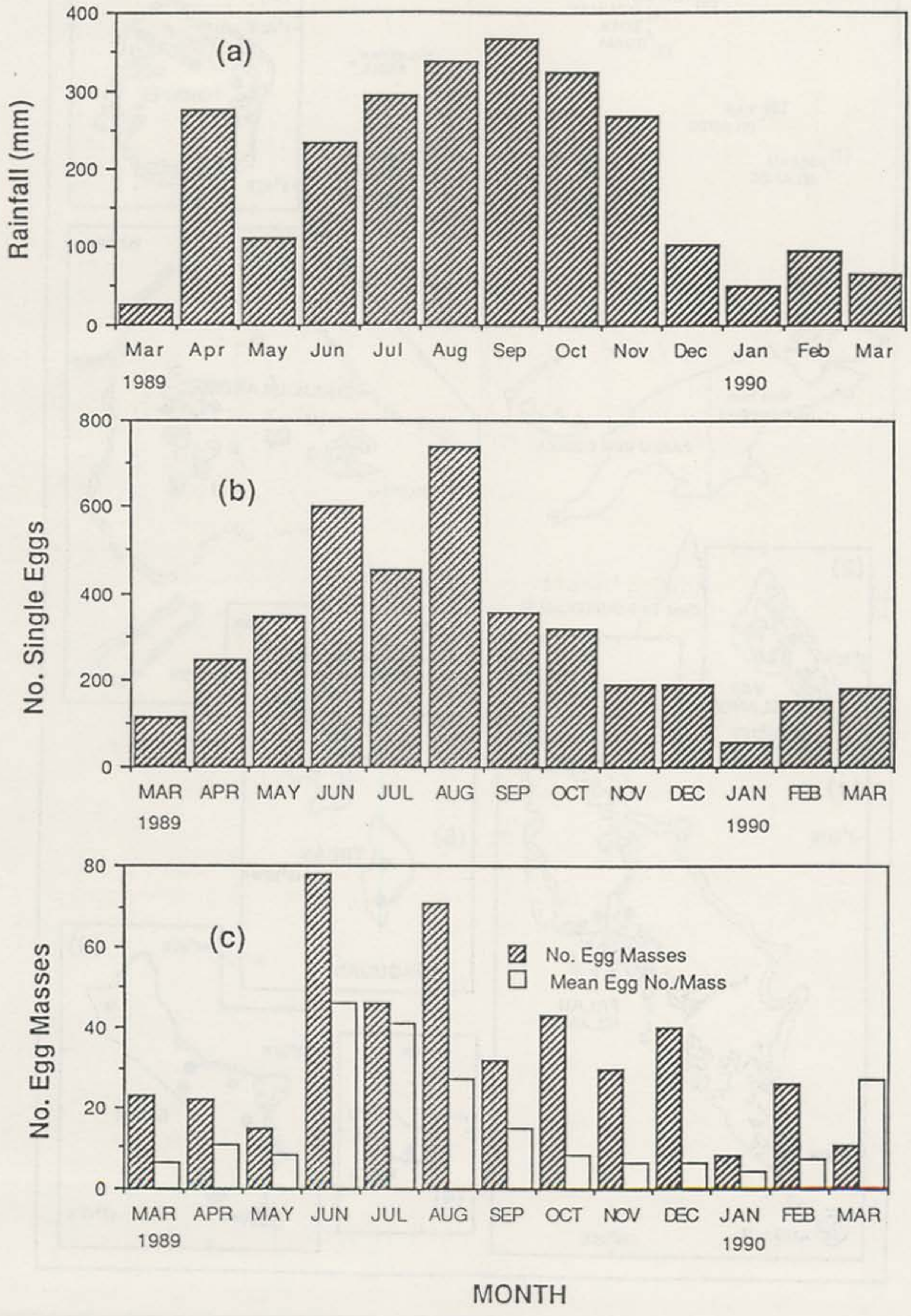
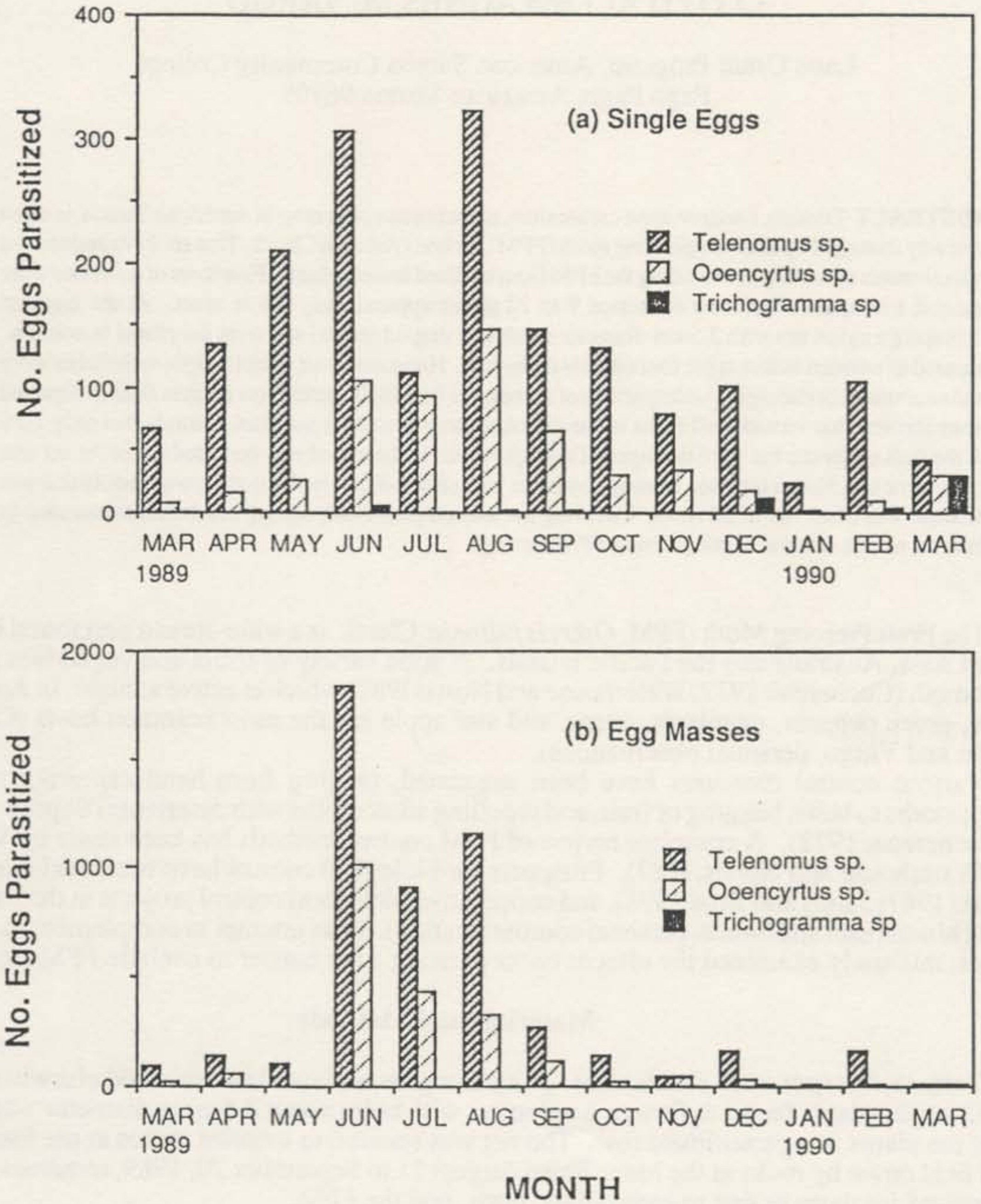


Figure 3. Number of fruit piercing moth eggs parasitized by various species of egg parasites.



THE EFFECTIVENESS OF A NET BARRIER IN EXCLUDING THE FRUIT PIERCING MOTH FROM TOMATO FRUIT IN AMERICAN SAMOA

LLOYD ALI and AGNES M. VARGO

Land Grant Program, American Samoa Community College
Pago Pago, American Samoa 96799

ABSTRACT Tomato, *Lycopersicon esculentum*, an important cash crop in American Samoa, is often severely damaged by the fruit piercing moth (FPM), *Othreis fullonia* Clerck. This study examined the effectiveness of netting in excluding the FPM from trellised tomato plants. Five rows of tomatoes were planted 1 m apart. Each row contained 9 to 12 plants approximtely 0.5 m apart. At the onset of flowering a nylon net with 2.5-cm diameter mesh was draped around and over the plants in one row, secured to wooden stakes at the four corners of the row. Harvested fruit were brought to the laboratory and examined for damage. A comparison of damage of fruit in the netted row against fruit in unnetted rows showed that virtually all fruits in the unnetted rows sustained puncture wounds, but only 20% of the fruit under the net were damaged. Damage to fruit in the netted row occurred when the net was close to or touching a tomato. Damage by birds was also reduced in the netted rows, but fruitworm damage was observed in all rows. Covering the tomato plant with netting can be recommended to farmers as one method of minimizing FPM damage.

The Fruit Piercing Moth (FPM, *Othreis fullonia* Clerck is a wide-spread pest found in Africa, India, Southeast Asia, Australia and the Pacific Islands. A wide variety of fruits and vegetables are attacked by the adult moth (Cochereau 1977; Waterhouse and Norris 1987) which is active at night. In American Samoa, tomatoes, green peppers, eggplants, citrus, and star apple are the most common hosts (Comstock 1963; Maddison and Vargo, personal observations).

Various control measures have been suggested, ranging from hand capturing moths at night, attracting moths to baits, bagging of fruit, and repelling adult moths with deterrents (Baptist 1945; Banziger 1982; Cochereau, 1972). A complete review of FPM control methods has been made by Waterhouse and Norris (Waterhouse and Norris, 1987). Prospects for biological control have been evaluated (Waterhouse and Norris 1987; Sands and Broe 1991), and cooperative biological control projects in the Pacific have been initiated (Muniappan and Sands, personal communication). In an attempt to complement biological control initiatives, this study examined the effectiveness of using a net barrier to exclude FPM from tomato fruit.

Materials and Methods

Tomato, *Lycopersicon esculentum* 'King Kong' was planted as described elsewhere (Vargo et al., 1991). Once the plants began to flower, a nylon net with holes about 2.5cm in diameter was draped around and over the plants in a penultimate row. The net was secured to wooden stakes at the four corners of the row and held down by rocks at the base. From August 21 to September 20, 1989, tomatoes were harvested and examined for damage due to caterpillars, birds, and the FPM.

Results and Discussion

The net prevented FPM damage to approximately 80% of the tomatoes in the netted row. Damage to netted tomatoes was low (15% or less) throughout the experiment except for tomatoes harvested on September 14 (Fig. 1a). On that date, many fruits were touching the net, which gave the FPM easy access. Consequently, it is important to build a framework for the net barrier with sufficient space that mature tomato plant are at least 5 cm from the net.

The net minimized bird damage (Fig. 1b) except on August 21 when a portion of the net accidentally opened. Approximately 40% of the total amount harvested was damaged.

The net was ineffective in keeping out adult moths of a tomato fruitworm, probably *Helicoperva armigera*. Caterpillar damage was noted on harvested fruit throughout the experiment (Fig. 1c). The adult fruitworm is smaller than the FPM. The wing-span of *H. armigera* is about 4 cm compared to 9 cm for the FPM. Fruitworm damage was higher on two dates (August 25 and September 1) in the rows without nets, but on August 21 and August 29 almost equal (20 to 25%) in the netted and non-netted rows. From September 4 to September 20, fruitworm damage was not observed. No explanation is offered for these observations, although environmental or climatical influences are possibilities.

In Integrated Pest Management (IPM) systems, various methods are employed to minimize the damage of pests on a crop. With increased concern for the environment, nonchemical methods are a priority. Employing the exclusion principle by using a net barrier significantly reduced FPM damage to tomato fruits. The use of netting with smaller diameter holes may also be effective in keeping out the tomato fruitworm. Construction of the net before the flowering stage may also reduce or prevent infestation by *H. armigera*. Eggs of *H. armigera* take 2 to 4 days to hatch, so it is important to construct the net before fruits are present.

While further replication and observation are necessary, we believe that the net barrier method would be a suitable IPM technique to recommend to farmers. Together with an active biological control program, we believe that the net barrier would be an important part of an IPM system of FPM control in American Samoa and elsewhere.

Acknowledgements

We thank Don Vargo for his assistance in preparing the figures.

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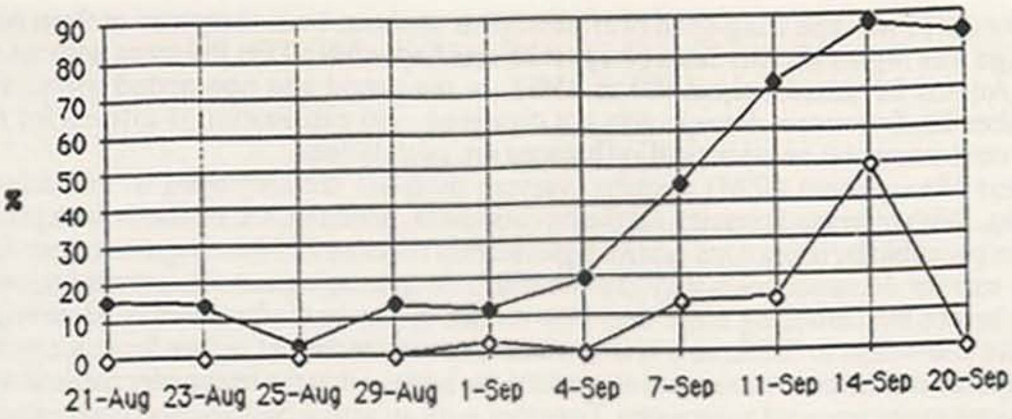
A.



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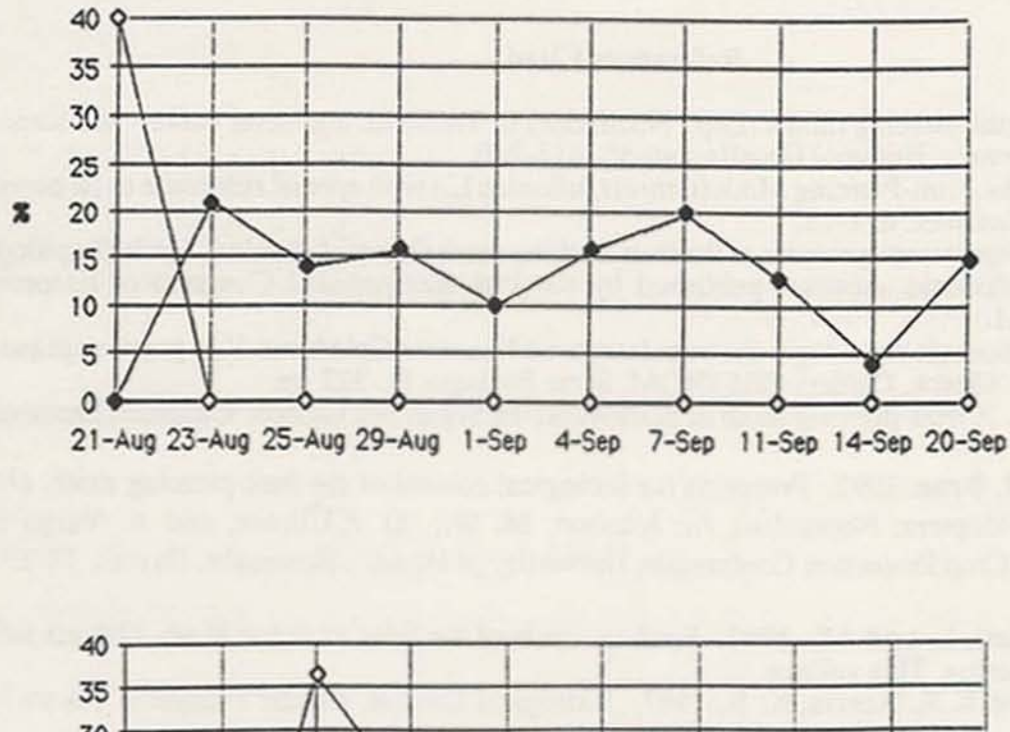

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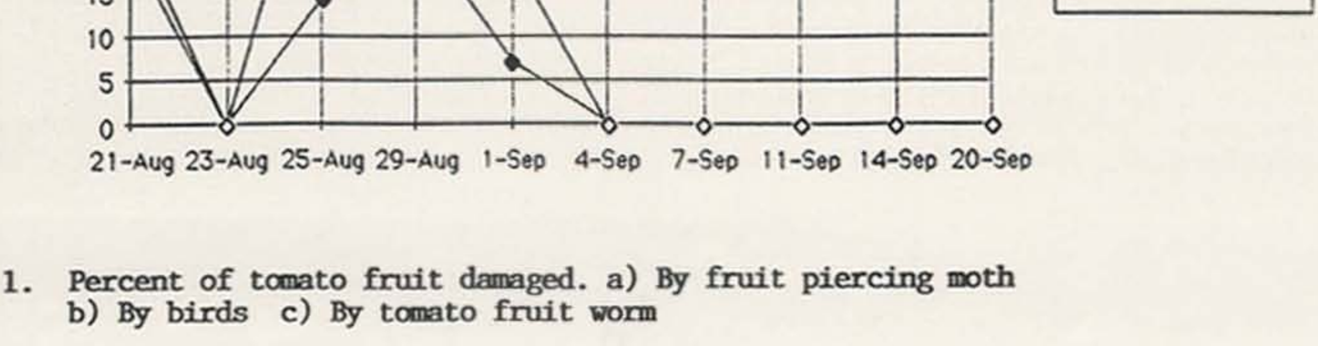

FIGURE 1. Percent of tomato fruit damaged. a) By fruit piercing moth b) By birds c) By tomato fruit worm

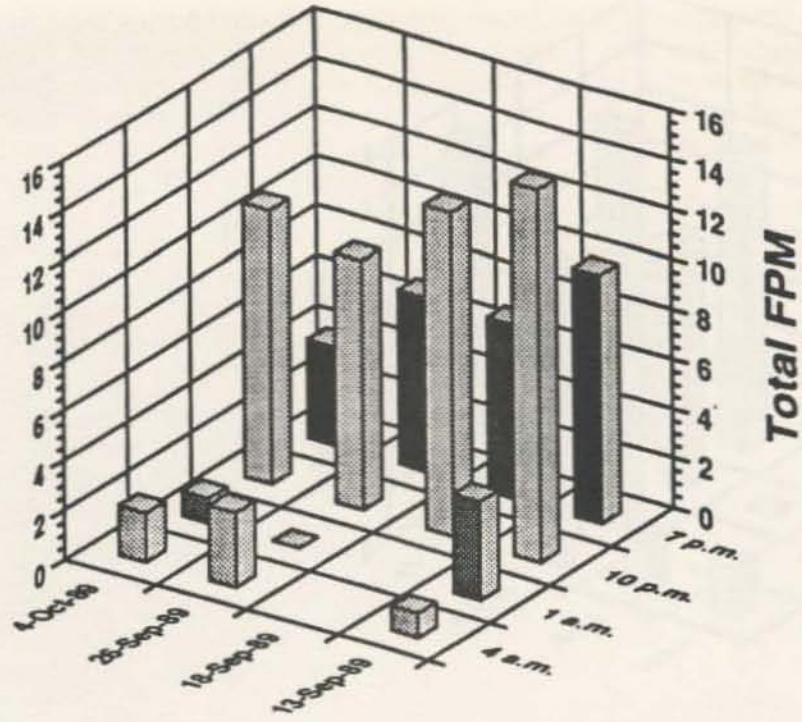

Figure 1. Total number of fruit piercing moths on tomato at night.

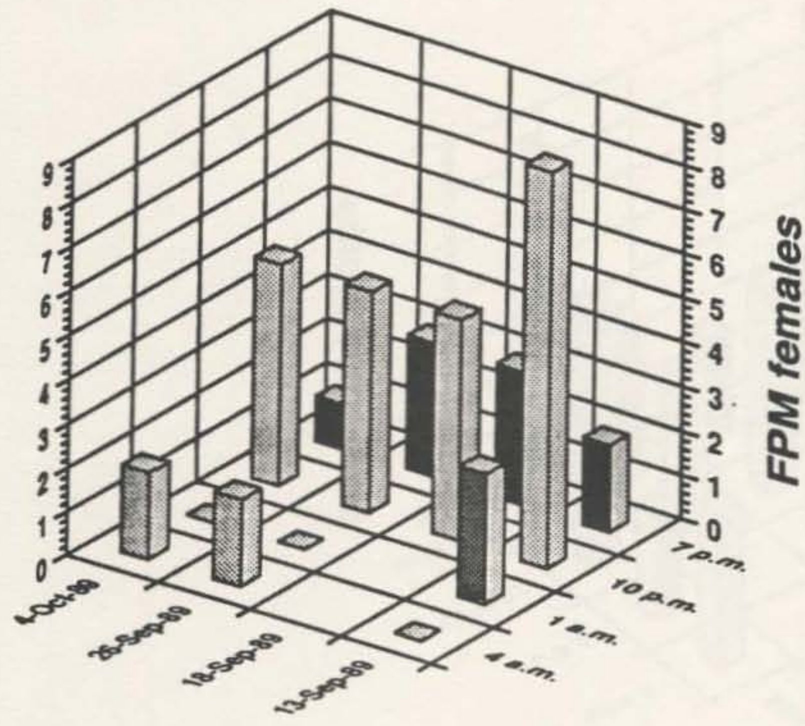

Figure 2. Number of fruit piercing moth females on tomato at night.

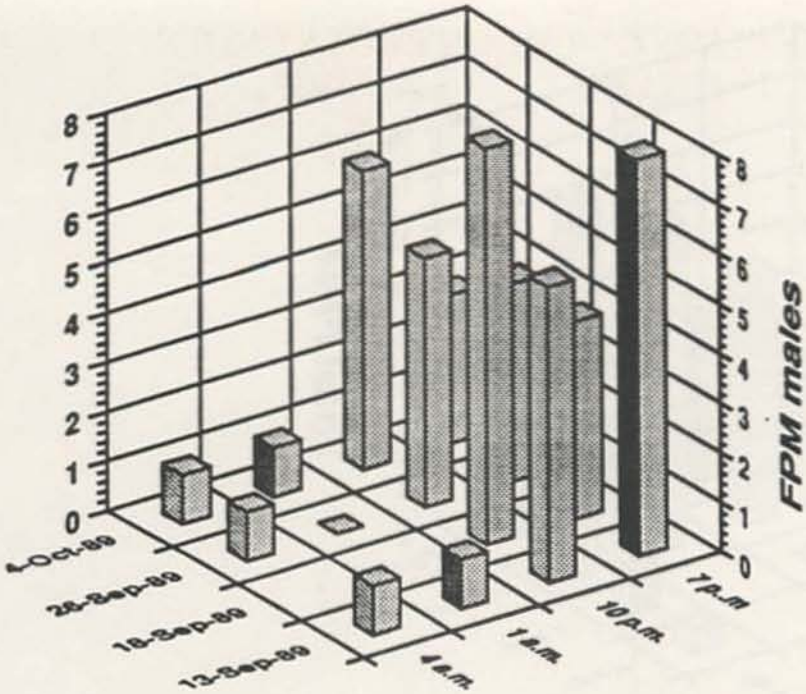

Figure 3. Number of fruit piercing moth males on tomato at nights.

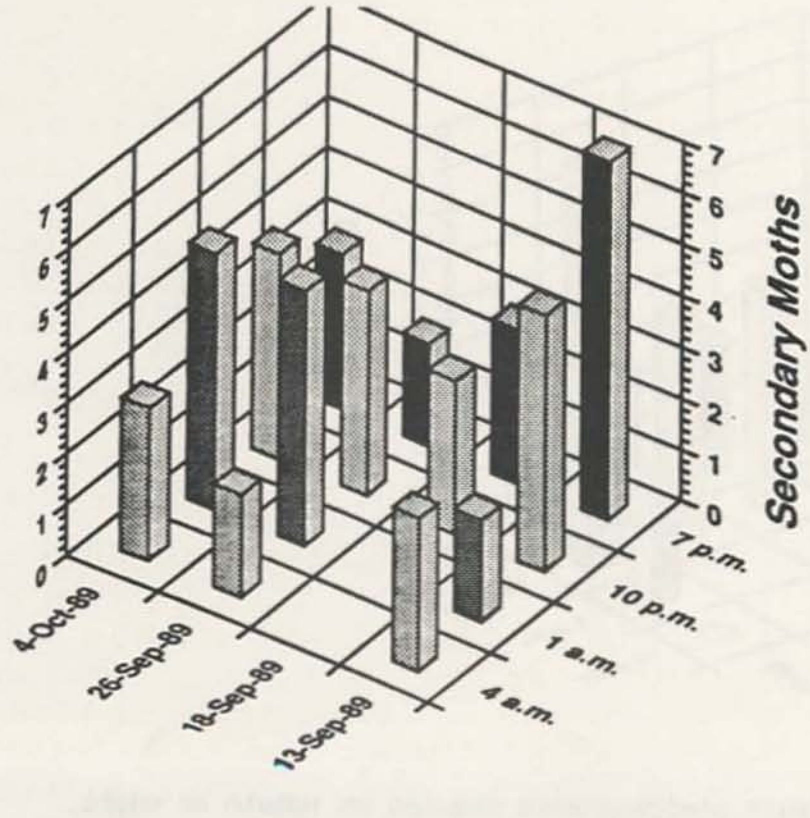

Figure 4. Total number of secondary fruit sucking moths on tomato at night.

HOST PREFERENCE OF PESTS ON CRUCIFEROUS CROPS IN GUAM

M. MARUTANI and R. MUNIAPPAN

Agricultural Experiment Station
College of Agriculture and Life Sciences
University of Guam
Mangilao, Guam 96923 USA

ABSTRACT Host preference of pests on cruciferous crops in Guam was studied. The pests included imported cabbage webworm, *Hellula undalis* (F.), cabbage cluster caterpillar, *Crocidolomia pavonana* Zeller, mustard aphid, *Lipaphis erysimi* (Davis), cluster caterpillar or cutworm, *Spodoptera litura* (F.), flea hopper, *Halticus tibialis* (Reuter), fire ant, *Solenopsis geminata* (F.), leaf miners, *Liriomyza* spp. and diamondback moth, *Plutella xylostella* (L.). *H. undalis* was found to be a serious pest on young seedlings of many crucifers. When head cabbage (*Brassica oleracea* L. *capitata*) was planted with other cruciferous crops in the field, *H. undalis* was attracted by radish (*Raphanus sativus* L.), Chinese cabbage (*B. pekinensis* cv. Tempest), and mustard (*B. juncea*) leaving head cabbage unaffected. Similarly, Chinese cabbage (cv. Tempest) was a trap plant for *C. pavonana*. Three crops, radish, Chinese cabbage (cv. Tempest) and mustard were also found to be good trap plants for *H. tibialis*. *L. erysimi* was attracted to mustard. The incidence of *S. geminata* and *Liriomyza* spp. was very low. *S. litura* occurs year round on head cabbage at certain locations while *P. xylostella* appears mostly in the dry season. Host preference of *P. xylostella* on Guam has not been identified.

Cruciferous crops on Guam are attacked by many arthropods. Major pests include the imported cabbage webworm, *Hellula undalis* (Fabricius), cabbage cluster caterpillar, *Crocidolomia pavonana* Zeller, mustard aphid, *Lipaphis erysimi* (Davis), corn earworm, *Helicoverpa armigera* (Hubner), cluster caterpillar, *Spodoptera litura* (Fabricius), diamondback moth, *Plutella xylostella* (L.), garden looper, *Chrysodeixis chalcites* (Esper), flea hopper, *Halticus tibialis* (Reuter), fire ant, *Solenopsis geminata* (Fabricius), and leaf miners, *Liriomyza* spp. (Muniappan, unpublished data). Some insects specifically feed on cruciferous crops while the others have a wide host range in other plant species.

When insects feed on crops, they exhibit preferences among host species. Pimentel (1961) observed significantly more larvae of *Pieris rapae* (L.) on Brussels sprouts and head cabbage than on broccoli, collards and kale when they were grown in the same field. He reported that *Brevicoryne brassicae* (L.) was more numerous on Brussels sprouts than on broccoli or collards. *Myzus persicae* (Subz.) was found more on collards and kale than on Brussels sprouts or head cabbage, and *Lygus* spp. were more abundant on collards than Brussels sprouts or head cabbage.

P. xylostella is one of the widely distributed pests of crucifers in the world. In North Carolina, Rudder and Brett (1967) found that *P. xylostella* preferred broccoli, rutabaga, Brussels sprouts, cauliflower, some varieties of head cabbage, collard and kale rather than radish, turnip, and mustard. Eckenrode et al. (1986) noted that mustard and Chinese cabbage were preferred host plants of *P. xylostella*. Finding that *P. xylostella* was attracted by mustard plants, Srinivasan and Krishna Moorthy (1988) developed a management program for controlling cabbage pests using mustard as a trap crop for *P. xylostella* in India. Hokkanen et al. (1986) successfully controlled rape blossom beetle, *Meligethes aeneus* on cauliflower by growing

Chinese cabbage, calebrese and oil seed rape as trap crops in Finland.

In this paper, we report major pests of cruciferous crops, *Brassica* species and *Raphanus sativus*, found in Guam and their host preferences.

Materials and Methods

Five trials were conducted at 4 different locations on Guam, Yigo, Dededo, Inarajan and Merizo from 1988 to early 1990. Yigo and Dededo are located in northern Guam. The soil of the two locations is classified as clayey, gibbsitic, nonacid, isohyperthermic, Lithic Ustorthents. Inarajan and Merizo are located in the south. The soil in the Inarajan field is classified as very fine, mixed, nonacid, isohyperthermic Aeric Tropic Fluvaquents and in Merizo it is very fine, kaolinitic, isohyperthermic Oxic Haplustalts. Prior to planting, all fields were prepared by disc plowing and tilling. Fertilizer,10-20-20 (N-P_2O_5-K_2O) at 1102 kg/ha, was incorporated in furrows. The fields were irrigated using drip systems. Hand weeding and application of insecticides were done as needed. All trials were arranged in a randomized complete block design with 3 or 4 replications. Each plot consisted of four rows with a distance of 1 m between rows. There were 8 or more plants in a row. The distance between adjacent plants was 0.46 m or less depending on plants. The population of each pest was recorded by counting the number of individuals on 10 plants in inner rows of each plot unless specifically stated. Head cabbage (*Brassica oleracea* var. *capitata*) and Chinese cabbage (*B. pekinensis*) were germinated in trays and transplanted when 3 to 4 week old. All other crops were germinated directly in the fields.

The first trial was initiated at Dededo on Oct. 12, 1988. Test plants were head cabbage (*B. oleracea* var. *capitata* 'KK Cross'), Chinese cabbage (*B. pekinensis* 'Tropicana)', broccoli (*B. oleracea* var. *italica*), pak choi (*B. chinensis*), rape (*B. napus* 'Dwarf Essex'), and radish (*Raphanus sativus* cv. 'Relish Cross'). There were three replications. Tribasic copper sulfate was sprayed at the rate of 3.9 ml/l on Nov. 1 to control a fungal disease. On Nov. 10, fenvalerate (Pydrin 2.4EC) was sprayed at the rate of 1.3 ml/l to control *S. litura* , otherwise there was a risk of losing the whole experiment. Occurrence of insect pests were examined on Nov. 3, 9, 14, 18, and 25.

The second trial was started at Merizo on Nov. 22, 1988. It consisted of three replications. Head cabbage (*B. oleracea* var. *capitata* 'C-O Cross'), Chinese cabbage (*B. pekinensis* 'Tropicana'), turnip (*B. campestris* cv. 'Just Right'), green mustard(*B. juncea*), and Brussels sprouts (*B. oleracea* var. *gemmifera* 'Jade Cross') were tested. Naled (Dibrom 8 EC) was sprayed at the rate of 2.6ml/l on Dec 3 and 15, 1988 to suppress *H. undalis* and *S. litura* and prevent the total loss of the experiment. The number of insects was counted on Dec. 12 and 19, 1988.

The third trial was initiated on Aug. 28, 1989 at the Yigo field. There were four replications. Crops tested included head cabbage (*B. oleracea* var. *capitata* 'C-O Cross'), Chinese cabbage (*B. pekinensis* 'Tempest' and 'Saladeer'), mustard (*B. juncea*) and turnip (*B. campestris* 'Tokyo Cross'). Insects were counted on Oct. 13 and 18, 1989.

The fourth trial was planted at Yigo on Nov. 24, 1989. There were four replications. Plants tested were head cabbage (*B. oleracea* var. *capitata* 'KK Cross'), Chinese cabbage (*B. pekinensis* 'Tempest'), green mustard (*B. juncea*), turnip (*B. campestris* 'Oasis'), kohlrabi (*B. oleracea* var. *gongylodes* 'Grand Duke'), and radish (*R. sativus* 'Minowase Summer No. 3'). Insects were counte on Jan 4 and 9, 1990. Data from *B. juncea*, *B. campestris* 'Oasis', and *B. oleracea* var. *gongylodes* 'Grand Duke' were eliminated from the analysis because large numbers of plants were missing due to poor seed germination caused by heavy rainfall and soil erosion.

The fifth trial was initiated at Inarajan on the same day as the fourth trial using the same six crops. The number of insects was counted on Dec. 27, 1989, Jan 5, 9, and 18, 1990. After harvesting turnip and kohlrabi, plots were cleared and plowed, and seeds of radish ('Minowase Summer No. 3' and 'South Pole') and Chinese cabbage 'Tempest' were germinated on Jan 19, 1990. Insect counts were made on Feb 21, 1990 to find out any differences in host preference by stages of plant development. During the second or third week in Trial 3, 4, and 5, young seedlings were sprayed with Naled (Dibrom 8 EC) at the rate of 2.6 ml/l to suppress a population of *H. undalis* which might have caused damage to terminal shoots and resulted in formation of multiple shoots. No insecticide applications were made afterwards.

All data were transformed to square root (X+0.5) before performing analysis of variance. Means separation was done by Duncan's multiple range test (SAS Institute Inc. 1985).

Results and Discussion

The pests observed and their population levels varied with time and location. In the first trial, *P. xylostella* was the major pest at Dededo field (Table 1). *P. xylostella* appeared on Nov. 3, and on Nov. 25 averaged 31.6 insects per 10 plants. On Nov. 18, Chinese cabbage 'Tropicana' and radish 'Relish Cross' had lower numbers of *P. xylostella* than the other four crops. However, the population of diamondback moth increased rapidly and 7 days later there was no significant differences in the number of diamondback moth larvae observed among the crops. Radish 'Relish Cross' had the lowest number (17.3 insects/10 plants) and head cabbage'KK Cross' had the highest number (40/10 plants) of insects. Other pests encountered were *Chrysodeixis chalcites*, *Hellula undalis*, *Spodoptera litura*, *Halticus tibialis*, *Aulacophora* sp. and *Liriomyza* sp. Because of a low population of these pests, it was not possible to compare their host preference.

In the second trial, the most common insect pests observed were *S. litura*, *Liriomyza* sp. and *H. ibialis* (Table 2). On Dec. 19, the number of *S. litura* was very high on head cabbage'C-O Cross' with 185.7 per 10 plants and Brussels sprout 'Jade Cross E' with 169.0/10 plants. There were no *S. litura* observed on turnip 'Just Right'. Chinese cabbage 'Tropicana' and green mustard had 27.7 and 40.4 insects per 10 plants, respectively. *Liriomyza* sp. seemed to be attracted to Chinese cabbage 'Tropicana' even though there was no significant difference in host preference of this pest in observations on both Dec. 12 and 19. *H. tibialis* was found more on Chinese cabbage followed by turnip and mustard. Head cabbage and Brussels sprouts had very few or no *H. tibialis*. On Dec 12 *H. undalis* was observed mostly on mustard.

The overall population of pests was low in the Trial 3. *H. undalis* and *H. tibialis* were the major pests (Table 3). On Oct. 18, more *H. undalis* were found on green mustard and turnip 'Tokyo Cross' than on head cabbage 'KK Cross', Chinese cabbage 'Tempest' and 'Saladeer'. On both Oct. 13 and 18, *H. tibialis* was observed on Chinese cabbage 'Tempest' and 'Saladeer', mustard and turnip 'Tokyo Cross', but none were found on head cabbage. *S. litura* was found mostly on head cabbage and not on mustard or turnip.

In Trial 4, *C. pavonana* was the major pest found on Chinese cabbage 'Tempest' (Table 4). Head cabbage 'KK Cross' and radish 'Minowase Summer Cross No. 3' were free of this pest on both Jan 4 and 9. *H. undalis* was more common on radish than head cabbage and Chinese cabbage 'Tempest'. *S. litura* favored head cabbage over Chinese cabbage and radish.

In the first part of the fifth trial, the highest number of insect pests was observed on Jan. 18, 1990 (Table 5). *C. pavonana* and *H. undalis* were the two main pests, and *H. tibialis* was present as a minor pest. Unlike the Yigo field, *S. litura* was not found at the Inarajan field. *C. pavonana* again showed greater preference for Chinese cabbage 'Tempest'. Head cabbage 'KK Cross', kohlrabi 'Grand Duke' and turnip 'Oasis' had no or very few *C. pavonana*. Radish 'Minowase Summer no. 3' had some *C. pavonana*. The observation on Jan. 18 revealed that this pest was attracted to inflorescences of green mustard. *H. undalis* favored green mustard and radish more than head cabbage, Chinese cabbage, and kohlrabi. *H. tibialis* was found more on Chinese cabbage, radish, turnip and green mustard. Head cabbage and kohlrabi had few or no *H. tibialis*.

The second part of the experiment in trial 5 included two developmental stages of Chinese cabbage 'Tempest ' and radish. Both head cabbage and green mustard were mature, the former forming large heads and the latter flowering and producing seeds. *C. pavonana*, *H. undalis*, *H. tibialis*, *L. erysimi* and *Liriomyza* sp. were recorded on Feb 21. Older plants of Chinese cabbage 'Tempest' had the highest numbers of *C. pavonana*, followed by flowering green mustard and young Tempest. No *C. pavonana* was observed on head cabbage or radish in either November or January plantings. About 35 *H. undalis* /10 plants were found on radish (Nov. planting) and flowering mustard, while other plants had less than 8 insects/10 plants. Younger radish (Jan. planting) attracted more *H. tibialis*. *L. erysimi* favoured mustard plants. Occasionally, *Liriomyza* sp. was observed on mustard.

H. undalis infested young seedlings in the nursery. Caterpillars of this insect fed on meristems and tender tissues of young leaves and bored into vascular systems of the plant. Because of its frequent occurrence in the field, we considered it to be the most serious pest of crucifers in Guam. One of the main reasons for its frequent occurrence is the present of an alternate host, *Gynandropsis pentaphylla*, in the fields. In the present experiment, *H. undalis* was more attracted by radish, mustard and turnip than by head cabbage when they were planted in the same field. This suggests that these crops can be utilized as trap crops to protect head cabbage from *H. undalis*. Once the preferred hosts start to develop, the young seedlings of head cabbage are protected. Similarly, Chinese cabbage 'Tempest ' and mustard plants can be used as trap crops for *C. pavonana*. *H. tibialis* was a minor pest. It preferred Chinese cabbage, mustard, turnip and radish to head cabbage. Another minor pest, *L. erysimi* , favoured mustard. Preferences of *S. geminata* and *Liriomyza* sp. were not determined due to low populations of these insects.

Although the incidence of *S. litura* varied from location to location, it preferred head cabbage to other crops (Tables 2-4). Unlike *P. xylostella* , which is more more common in the dry season, *S. litura* occurred in both the dry and wet seasons. Since head cabbage is the most preferred plant of *S. litura*, chemical or/and other control methods for this pest should be evaluated.

During the experiment, the diamondback moth, *P. xylostella* occurred only in the first trial, and because of its extremely high population, we could not determine its host preferences. Excepts for mustard, all crops tested in the first trial were heavily infested by diamondback moth. Mustard plants developed as a trap crop in India (Srinivasan and Krishna Moorthy 1988) are being evaluated in Guam.

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Table 1. Average number of *Plutella xylostella* on 10 plants observed in Trial 1 conducted from Oct. 12 - Nov. 28, 1988 at Dededo.

Plant	Nov.3	Nov.9	Nov.14	Nov.18	Nov.25
Brassica oleracea var. *capitata* 'KK cross'	0.3 b [1]	0.0 a	1.7 a	20.3 ab	40.7 a
Brassica pekinensis 'Tropicana'	0.3 b	0.7 a	2.7 a	8.7 bc	36.0 a
Brassica oleracea var. *italica*	0.0 b	0.0 a	8.0 a	31.3 a	39.7 a
Brassica chinensis 'White pak choi'	2.0 a	2.0 a	2.7 a	26.7 a	34.0 a
Raphanus sativus 'Relish cross'	0.0 b	0.0 a	2.7 a	4.7 c	17.3 a
Brassica napus 'Dwarf Essex'	0.0 b	1.0 a	2.3 a	16.0 abc	22.0 a
Mean	0.4	0.6	3.4	17.9	31.6
CV (%)	22.2	43.6	53.6	26.7	30.4

[1] Values in each column followed by the same letter are not significantly different at p=0.05, DMRT. Data were transformed to square root (X+0.5) before performing analysis of variance. Original means are shown in the table. Data on Nov. 25 had four missing data. There were no data taken from rep 1 and rep 3 of *Brassica pekinensis* 'Tropicana' and from rep 1 and 2 of *Brassica napus* 'Dwarf Essex' due to an outbreak of a microbial disease. ANOVA was conducted entering these as missing data.

Table 2. Average number of insects on 10 plants observed in Trial 2 conducted from Nov. 22 - Dec. 30, 1988 at Merizo.

Plant	*Spodoptera litura*		*Liriomyza sp.*		*Halticus tibialis*		*Hellula undalis*
	Dec. 12	Dec. 19	Dec. 12	Dec. 19	Dec. 12	Dec. 19	Dec. 12
Brassica oleracea var. *capitata* 'C-O cross'	18.7 a[1]	185.7 a	5.9 a	4.3 a	0.3 b	0.0 c	0.7 b
Brassica pekinensis 'Tropicana'	0.3 a	27.7 bc	21.0 a	11.3 a	16.3 a	7.7 a	1.7 b
Brassica oleracea var. *gemmifera* 'Jade cross E'	21.3 a	169.0 a	1.0 a	2.0 a	0.0 b	0.0 c	0.0 b
Brassica juncea (green mustard)	1.7 a	40.3 b	3.7 a	4.0 a	5.7 ab	1.3 bc	5.7 a
Brassica campestris 'Just Right'	0.3 a	0.0 a	7.7 a	8.0 a	8.3 ab	2.3 b	2.0 b
Mean	8.5	84.5	7.8	5.9	6.1	2.3	2.0
CV (%)	99.0	34.2	65.4	51.3	53.9	25.8	37.4

[1] Values in each column followed by the same letter are not significantly different at p =0.05, DMRT. Data were transformed to square root (X+0.5) before performing analysis of variance. Original means are shown in the table.

Table 3. Average number of insects per 10 plants observed during Trial 3 conducted from No. 22-Dec. 30, 1988 at Yigo.

Plant	*Hellula undalis*	*Halticus tibialis*		*Spodopta litura*	
	Oct. 18	Oct.13	Oct.18	Oct. 13	Oct.18
Brassica oleracea var. *capitata* 'K-K cross'	1.0 b[1]	0.0 b	0.0 c	3.3 a	6.3 a
Brassica pekinensis 'Tempest'	2.5 b	8.5 a	13.5 a	1.0 b	0.0 b
Brassica pekinensis 'Saladeer'	1.0 b	2.8 ab	5.0 b	0.3 bc	3.3 ab
Brassica juncea (green mustard)	15.0 a	6.3 a	11.8 a	0.0 c	0.0 b
Brassica campestris 'Tokyo cross'	14.3 a	4.3 a	8.8 ab	0.0 c	0.0 b
Mean	6.8	4.4	7.8	0.9	1.9
CV(%)	28.8	36.7	28.9	28.2	55.6

[1] Values in each column followed by the same letter are not significantly different at p=0.05, DMRT.
Data were transformed to square root (X+0.5) prior to performing ANOVA. Original means are shown in the table.

Table 4. Average number of insects per 10 plants observed during Trial 4 conducted from Nov. 24, 1989 to Jan. 10, 1990 at Yigo.

Plant	*Crocidolomia pavonana*		*Hellula undalis*		*Spodoptera litua*	
	Jan.4	Jan.9[1]	Jan.4	Jan. 9[1]	Jan 4	Jan. 9[1]
Brassica oleracea var. *capitata* 'KK cross'	0.0 b[2]	0.0 b	0.0 b	0.3 b	6.8 a	6.3 a
Brassica pekinensis 'Tempest'	64.8 a	110.5 a	0.3 b	0.8 b	0.0 b	0.0 b
Raphanus sativus 'Minowase summer cross No. 3'	0.0 b	0.0 b	5.5 a	28.0 a	0.3 b	0.0 b
Mean	21.6	36.8	1.9	9.7	2.4	2.1
CV(%)	42.8	25.9	32.5	35.1	54.0	50.4

[1] There were 6 radish plants observed instead of 10 in replication 4 on Jan 9.
[2]Values in each column followed by the same letter are not significantly different at p =0.05, DMRT. Data were transformed to square root (X+0.5) prior to performing ANOVA. Original means are shown in the table.

Table 5. Average number of insects per 10 plants observed during Trial 5 conducted from Nov. 24, 1989 to Feb. 21, 1990 at Inarajan.

Plant	*Crocidolomia pavonana*			*Hellula undalis*		*Halticus tibialis*			
	Jan.5	Jan.9	Jan.18	Jan.9	Jan. 18	Dec. 27	Jan 5	Jan. 9	Jan. 18
Brassica oleracea var *capitata* 'KK cross'	0.0b[1]	0.0c	0.0c	0.3b	0.3c	0.0c	0.0c	0.0b	0.0b
Brassica pekinensis 'Tempest'	10.0a	47.5a	51.5a	0.3b	0.0c	1.3bc	5.3b	17.3a	18.8a
Brassica juncea (green mustard)	0.0b	0.0c	7.0b	7.0a	31.1a	5.5a	9.8ab	10.8a	5.0ab
Brassica campestris 'Oasis'	1.0b	0.0c	0.0c	3.0ab	13.5b	2.3b	9.0ab	14.3a	8.5ab
Brassica oleracea var. *gongylodes* 'Grand Duke'	0.0b	0.0c	0.0c	0.3b	0.0c	0.0c	0.5c	0.0b	0.0b
Raphanus sativus 'Minowase summer no.3'	1.8b	7.3b	9.5b	5.8a	28.3a	3.5ab	12.5a	19.3a	14.5ab
Mean	2.1	9.1	11.3	2.8	12.2	2.1	6.2	10.3	7.8
CV(%)	70.5	52.6	33.8	27.9	45.6	31.9	26.9	36.5	69.9

[1] Values in each column followed by the same letter are not significantly different at p=0.05, DMRT. Data were transformed to square root (X+0.5) prior to performing ANOVA. Original means are shown in the table.

Table 6. Average number of insects per 10 plants observed on Feb. 21, 1990 in Trial 5 at Inarajan.

Plant	*Crocidolomia biotalis*	*Hellula undalis*	*Halticus tibialis*	*Lipaphis erysimi*	*Liriomyza* sp.
Brassica oleracea var *capitata* 'KK cross'	0.0 d[1]	0.3 b	0.0 b	0.0 b	0.0 a
Brassica pekinensis 'Tempest '(Nov. planting)	97.8 a	0.8 b	5.3 b	75.0 b	0.0 a
Brassica pekinensis 'Tempest '(Jan. planting)	10.3 c	7.5 b	10.5 b	0.0 b	0.0 a
Raphanus sativus 'Minowase summer no.3' (Nov. planting)	0.0 d	36.3 a	1.5 b	0.0 b	0.0 a
Raphanus sativus 'Minowase summer no.3' and 'South pole' (Jan. planting)	0.0 d	6.8 b	37.0 a	0.0 b	0.0 a
Brassica juncea (green mustard) (Flowering)	32.3 b	34.5 a	0.0 b	279.8 a	2.0 a
Mean	23.4	14.4	9.1	59.1	0.3
CV(%)	30.1	34.7	59.2	84.4	43.7

[1]Values in each column followed by the same letter are not significantly different at p =0.05, DMRT. Data were transformed to square root (X+0.5) prior to performing ANOVA. Original means are shown in the table.

INSECT PESTS OF CUCUMBER IN AMERICAN SAMOA AND THEIR BIOLOGICAL CONTROLS

LLOYD ALI and AGNES M. VARGO

Land Grant Program, American Samoa Community College
Pago Pago, American Samoa 96799

ABSTRACT Cucumber (*Cucumis sativus*), an important cash crop in American Samoa, is host to several insect pests. This study was conducted to identify the major insect pests and their native biological controls. Nine varieties of cucumber were planted at the Land Grant Station in American Samoa using a randomized complete block design. Insect counts were made twice weekly, starting one week after seedling transfer. *Aphis gossypii* and *Thrips palmi* were the first pests to appear, a week and a half after transplanting. *Thrips palmi* populations were low throughout the experiment. Numbers of *Aphis gossypii* increased initially but were markedly reduced in approximately three weeks by a complex of predators that included: syrphid fly larvae, lacewing (*Chrysopa* sp.) larvae and adults, adults and larvae of a ladybeetle with six spots and several species of spiders. Other minor pests observed during this period were *Leptoglossus australis* and *Epilachna* sp. Cucumber variety did not appear to influence pest incidence.

Cucumber, *Cucumis sativus*, is an important vegetable in American Samoa grown for home consumption and for sale at the local market. Farmers on Tutuila, the largest island of American Samoa, report that several pests threaten their cucumber crop throughout the year. The purpose of this study is to identify major cucumber pests present at this time and to determine if there are endemic biological controls suppressing these pests.

Materials and methods

Seeds of nine varieties of cucumber obtained from the Known-You Seed Co., 26 Chung Cheng Road, Kohsiung, Taiwan, R.O.C., were sown Feb. 12, 1990 in 5 x 5 x 5 cm peat pots containing Jiffy Mix Plus medium. After the first true leaves appeared, the seedlings were fertilized every 5 days with 50 ml of a 1% solution of 5-52-8 water soluble fertilizer. Four 18-day-old seedlings of each variety were transplanted, in a randomized complete block design, spaced 50 cm apart in a square pattern. Blocks within rows were separated by 90 cm; each row was 2 m apart. Each variety had 3 replicates. Each transplant hole contained 10 g of 8-20-11-11(s)-0.3 (Zn) fertilizer, and each plant was treated with a side-dressing of 20 g of 16-16-16 fertilizer 13, 26, and 39 days after transplanting. The vines were trained to climb a 1.5 m trellis. The field was mulched with a thick layer of coconut fronds. Fruit was harvested 3 times a week between Mar. 23 and Apr. 25. During this period temperatures ranged from 21° to 32° C, averaging 25° C.

Insect counts were made twice a week on all varieties from Mar. 8 to Apr. 16. A leaf from the vine tip, midsection and base of 1 of the 4 plants in each block was examined and all insects and spiders seen were counted. Leaves were taken from three vertical levels to determine which level would most accurately represent the total aphid population, thus assisting in the development of a suitable Integrated Pest Management (IPM) sampling plan.

Results and discussion

Aphis gossypii and *Thrips palmi* were the first pests to infest the cucumbers. *T. palmi,* which had been noted as a serious pest by the authors previously, was present in low numbers and caused no noticeable damage throughout this experiment. The population of *A. gossypii* varied. The maximum occurred on Mar. 23, three weeks after transplanting. Ten days later, the population of aphids dramatically decreased (Fig. 1). The biological control complex increased as the aphid population increased. Biological control agents observed were syrphid fly larvae, lacewing (*Chrysopa* sp.) adults and larvae, ladybeetle adults with six spots and their larvae and several kinds of spiders. Peak densities of ladybeetles, lacewings and spiders occurred shortly after aphid densities peaked (Fig. 2), suggesting a direct relationship or numerical response between predator and prey. Other studies indicate that there is a high degree of density dependence in the relationship between aphids and their coccinellid predators (Frazier 1988). Noting the relative number of aphids and coccinellids can be a part of the scouting survey in an IPM program for farmers in American Samoa.

The number of spiders peaked on Apr. 2. Spiders have been found to play a part in restraining pest outbreaks during the period of initial pest increase and are considered well suited for pest control (Sunderland 1988). Once on a crop, they will remain even if food is scarce. Because of their low metabolic rate, they can survive months without food. Several species of spider were found on the cucumber leaves. (Riechert and Lockley 1984) noted that biological control is facilitated by a whole spider community rather than by a single species. Thus it is important to conserve a diverse spider fauna.

Lacewings were most abundant from Mar. 23 to Apr. 2, indicating a density dependent relationship with the aphids. The three larval instars are active predators and factors of high longevity, high fecundity and fast development rates make lacewings, in general, good predators (New 1988).

Syrphid fly larvae were seen on three days, with the majority (60%)appearing on Mar. 23. The impact of syrphids can be substantial and may be attributed to a number of factors: 1) the mobility and searching ability of the adult female; 2) the habit, in certain species, of depositing eggs among the larval food; 3) the rapid rise in voracity as the larva grows (Chambers, 1988).

The decline of aphids by April 290 was followed by a decline of all the predators associated with the aphids.From these observations, it is a evident that an active and effective biological control complex exists for *A. gossypii* in American Samoa. It is possible that these predators could also be responsible for the control of *T. palmi*. The use of insecticides is minimal throughout the island. Consequently, biological control has been able to function to its fullest potential.

A similar biological control complex for *A. gossypii* was observed by the authors when these aphids infested taro. Other insects observed on cucumber included honey-dew collecting ants.

In developing a sampling plan for estimating the number of aphids, the majority of aphids were found on the leaf at the base of the plant (Fig. 3) Aphids were also found on the middle leaf and at the leaf at the tip. A regression analysis was conducted on the number of aphids at each of the three positions to determine the best sampling area. While r was 0.98 at mid leaf and 0.99 at the leaf base (Fig. 4) it is suggested that mid leaf is a more ideal sampling area because of the smaller number of aphids that need to be counted to give an accurate estimation. The high counts on lower leaves corresponds with the preference of some aphids for senescent leaves (Klingauf 1988). The main differences between mature and senescent leaves is the proportion of two major nutritional requirements: nitrogen and carbohydrates. As the leaf ages the amino acid concentration increases and the carbohydrate portion decreases. Besides nutritional components, other factors such as amount of shadow, sunshine, and humidity levels may also affect aphid preference (Klingauf 1988).

Other pests seen occassionally were *Leptoglossus australis*, the leaf-footed bug, and *Epilachna* sp. Previously, the authors had observed severe damage due to these pests. Present damage was negligible, suggesting that factors such as seasonality, amount of rainfall, location on island, and/or suitability of environment for biological controls may be responsible for cucumber pest fluctuations in American Samoa. Further investigation is needed in this area.

Acknowledgments

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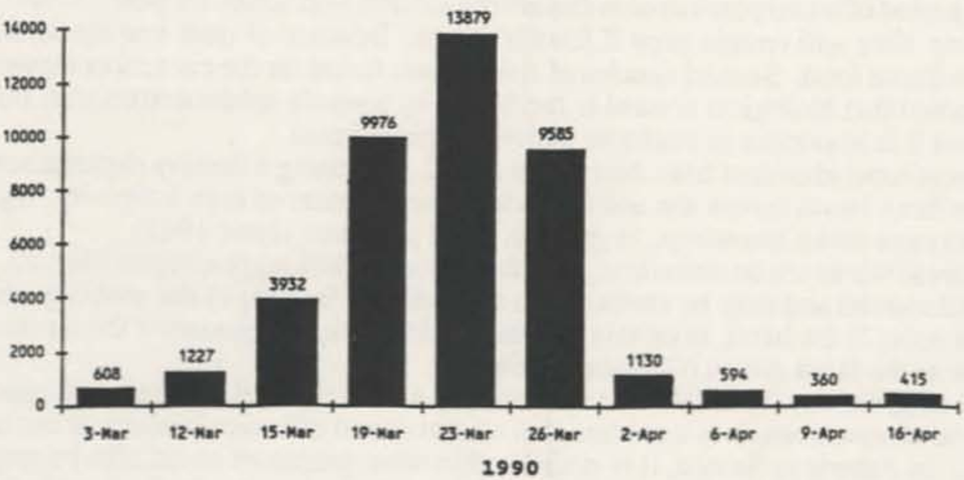

Figure 1. Population of aphids on cucumber leaves.

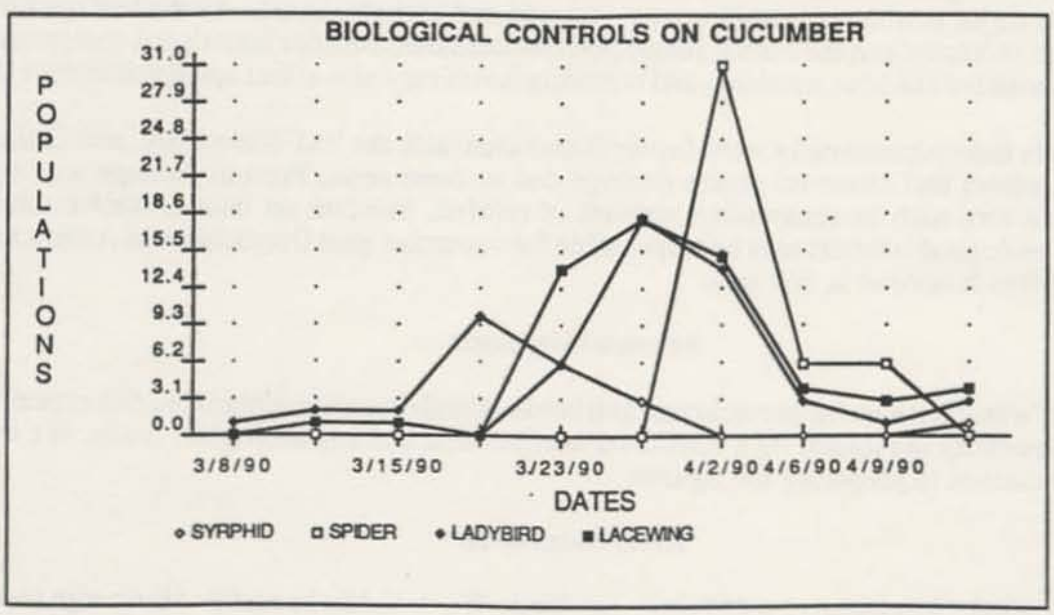

Figure 2. Number of predatory insects per sample on cucumber.

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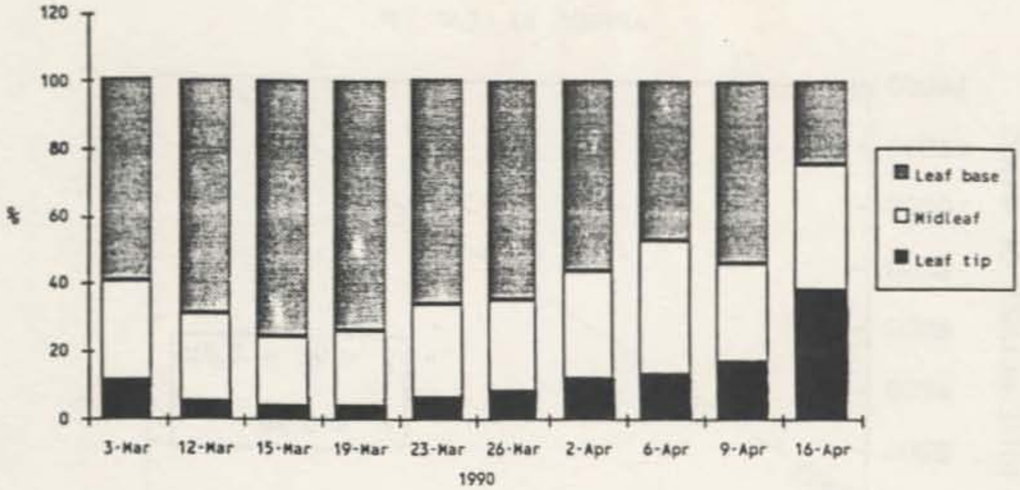

Figure 3. Location of aphids on cucumber leaves.

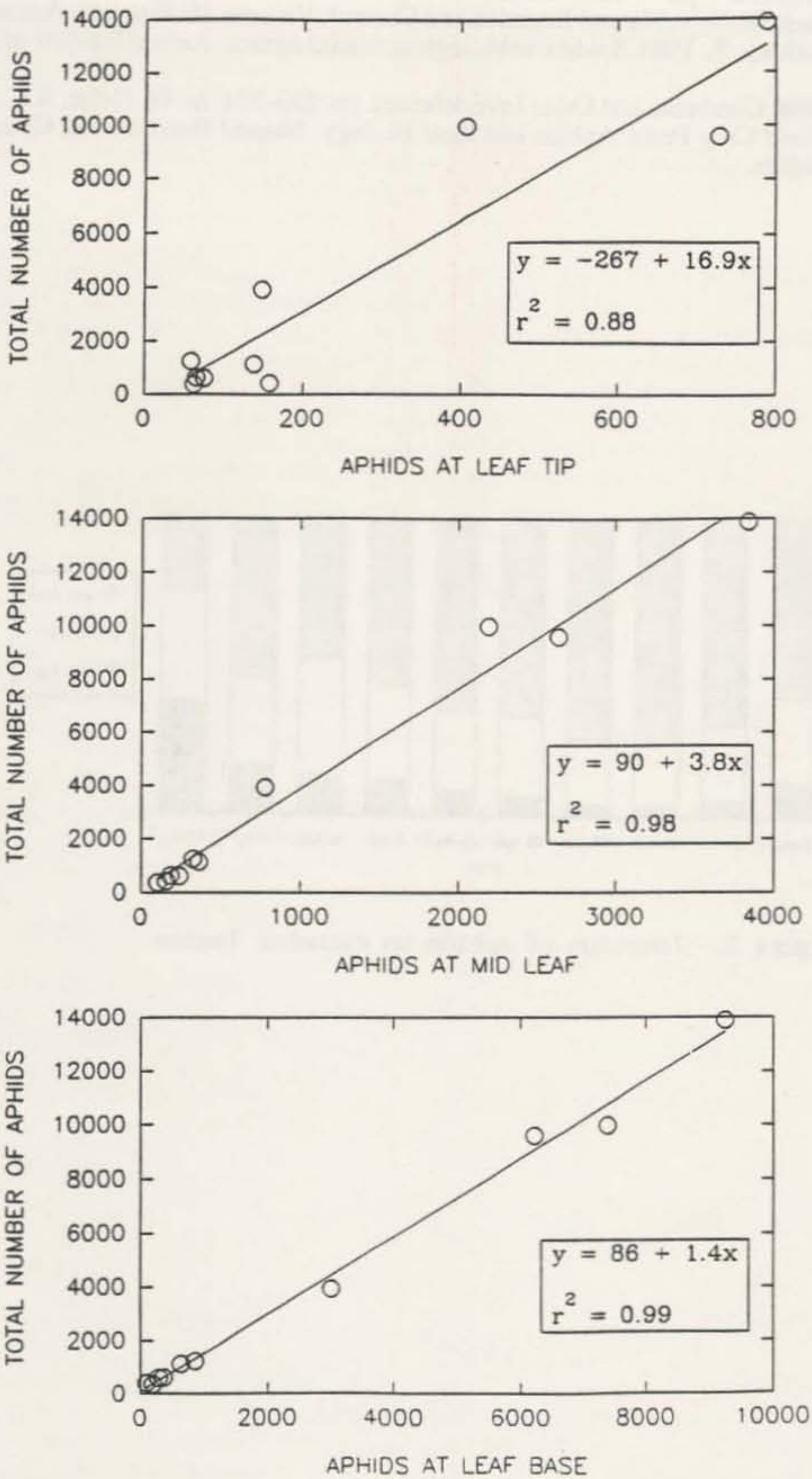

Figure 4. Correlation between total number of aphids on a cucumber leaf and number of aphids on selected parts of the leaf.

CUCURBIT DISEASES ON GUAM

G. C. WALL

Agricultural Experimant Station, College of Agriculture & Life Sciences,
University of Guam, Mangilao, GU, 96923

ABSTRACT Twenty-two pathogens have been reported on cucurbit crops on Guam; fourteen of these occur on watermelon, which is our most important crop today. The list includes 12 fungi, 4 bacteria, 3 viruses, 1 nematode, 1 parasitic plant and 1 physiological disease. Recently, the most economically important diseases have been fruit blotch, causing severe losses in the rainy season, powdery mildew, and virus diseases; Watermelon Mosaic I and Zucchini Yellow Mosaic are widespread, affecting all cucurbit crops. Wild hosts have been found to harbor these viruses. Powdery mildew is most important on cucumber, squash and bittermelon. Damping-off, caused mostly by *Pythium* sp., affects all cucurbits, and can seriously reduce plant stand. Later in the season, *Fusarium sp.* causes wilt in mature plants. Our recent research efforts have concentrated on virus diseases and on fruit blotch.

Cucurbits are very important on Guam and throughout Micronesia. While Guam's most economically important crop is watermelon, a large variety of other cucurbit crops are also popular. Local markets offer bittermelon, cucumber, melons of different types, pumpkin tips, squashes and watermelon. Many diseases are shared by these crops, and are therefore treated grouped together here.

The following is an updated report of all diseases identified on plants of the family Cucurbitaceae on Guam. It is of interest to regulatory agencies and agricultural workers in general to have access to updated information of this nature. Many of the diseases included here have been previously reported (Russo et al. 1985, Wall 1988). Viral diseases previously reported, however, had only been identified on the basis of symptoms. The causal agents in this report include fungi, bacteria, viruses, a nematode and a parasitic plant.

Materials and Methods

The information presented herein has been gathered through a period of several years. The bulk of the work has been done as part of the diagnostic service offered to all Guam residents by the University of Guam's College of Agriculture and Life Sciences. Identification of fungi and nematodes are based on taxonomic keys (Mai & Lyon 1975, Barnett & Hunter 1972, Ainsworth 1967, Alexopouos & Mims 1979, Chupp 1953, CMI Descriptions). Bacterial identifications are based on symptoms, gram reaction, colony morphology and medium utilization, etc. (Schaad 1980). Virus identifications are based on ELISA procedures (Yudin et al. 1990).

Results

The total number of pathogens found so far affecting the *Cucurbitaceae* on Guam is 22. This number includes 12 fungi, 4 bacteria, 3 viruses, 1 nematode, 1 parasitic plant and 1 important physiologic disorder (Table 1). Of these, 14 different diseases have been reported on watermelon (Table 2).

The most important diseases currently are: fruit blotch, virus diseases, and powdery mildew. Blossom end rot is quite common on watermelon during dry season plantings. Powdery mildew and virus diseases are most severe on squashes.

Considerable attention has been given to fruit blotch of watermelon since its first appearance in 1987. It has caused several devastating epidemics in recent years (Wall and Santos 1988, Wall 1989, Wall et al. 1990). Table 3 presents a summary of our work on fruit blotch, a disease that was first reported in watermelon fields in the southeastern United States in 1989, also causing severe epidemics there.

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Table 1. Cucurbit diseases reported on Guam: Fungi.

Pathogen	Disease
Fungi	
Erysiphe cichoracearum (anamorph *Oidium*)	Powdery Mildew
Glomerella cingulata	Anthracnose
(anamorphs *Colletotrichum* & *Gloeosporium*)	
Isariopsis griseola	Leaf spot
Cercospora citrullina	Leaf spot
Phyllosticta sp.	Leaf spot
Mycosphaerella citrullina	Gummy stemblight,
(syn. *M. melonis, Didymella bryoniae*)	Black rot
(anamorphs *Ascochyta, Phoma*)	
Rhizoctonia sp.	Damping off
Pythium sp.	Damping off
Pythium aphanidermatum	Cottony leak
Sclerotium rolfsii	Southern blight
Fusarium sp.	Wilt
Bacteria	
Erwinia carotovora	Soft rot
Pseudomonas lachrymans	Angular leaf spot
P. solanacearum	Wilt
P. pseudoalcaligenes subsp. *citrulli*	Fruit blotch
Viruses	
Cucumber Mosaic Virus	Cucumber mosaic
Watermelon Mosaic Virus I	Watermelon mosaic
(syn. Papaya Ringspot Virus - W)	
Zucchini Yellow Mosaic Virus	Zucchini yellow mosaic
Other	
Eragrostis amabilis	Parasitic plant
Physiologic	Blossom end rot
Meloidogyne incognita	Root-knot

Table 2. Cucurbit diseases on Guam listed by crop.

Pathogen or Disease	Water melon	Melons	Cucumber	Squash	Bitter melon	Other
Angular leaf spot		√				
Anthracnose	√		√			√
Bacterial wilt	√					
Blossom end rot	√					
Cercospora leaf spot		√			√	
Cottony leak			√		√	
Cucumber mosaic						√
Eragrostis	√					
Fruit blotch	√					
Fusarium	√	√	√			
Isariopsis			√			
Powdery mildew	√	√	√	√	√	√
Pythium damping off	√		√		√	
Rhizoctonia			√			
Root knot		√	√			
Sclerotium	√	√				
Soft rot	√					
Watermelon mosaic 1	√	√	√	√	√	√
Zucchini yellow mosaic	√			√		

Table 3. Summary of work on Fruit Blotch of watermelon.

Work done on Guam:

•Koch's postulates completed with a gram negative bacterium.

•Comparisons with *Pseudomonas pseudoalcaligenes* subsp. *citrulli* type culture.

•Initial identification procedure agrees with *P. pseudoalcaligenes* subsp. *citrulli.*

•Symptoms agree with those described earlier in U. S. and Australia, caused by *P. pseudoalcaligenes* subsp. *citrulli.*

•95 carbon sources now being tested.

•Seedling tests - pathogenic on watermelon seedlings.

•Seed inoculations - can result in seedling infections.

•Survival in seed - Seed from infected watermelon fruit produced infected seedlings after 9 months in storage at 5°C.

•Fruit inoculation of cultivars - apparent differences in reaction.

•Fruit inoculation in field - technique being developed for resistance

•Seed testing - commercial seed not found infested yet; seed from infected fruit = infected seedlings.

•Persistence in soil - pathogen can survive in soil at least 1 wk.

•Dissemination - disease can spread to adjacent seedlings.

•Seed heat treatment - inoculated seed successfully treated; seed from infected fruit - inconclusive.

BIOLOGY AND DEVELOPMENT OF THE ORANGE PUMPKIN BEETLE ON GUAM

DONALD NAFUS

College of Agriculture and Life Sciences
Agricultural Experiment Station
Mangilao, Guam 96923

ABSTRACT *Aulacophora similis* was reared on several hosts in the laboratory. Bittermelon, sweet potato, corn, and pechay were unsuitable for larval development. On seedlings of watermelon, the beetles took 42 days to develop to adults at 26° C. The larvae also developed on watermelon rind, but development took longer, 47 days, particularly for the first and second instars. On pumpkin seedlings development rates were about the same as for watermelon seedlings, 44 days, but survival was not as good.

In intercropped plants of several Cucurbitaceae, the beetles showed a distinct preference for zucchini, local pumpkin, honeydew, and cantaloupe. Cucumber, pepino, luffa, and watermelon were less attractive. Although the beetles were found sitting on luffa, no feeding damage was noted, suggesting it is not a preferred adult host. No beetles were observed on bittermelon.

The genus *Aulacophora* contains over 160 species in Africa, Europe, Asia, Australia, and many Pacific islands (Waterhouse & Norris 1987). In Micronesia there are seven species, four of which occur in the Marianas (Gressitt 1955). Of these, two are rare, one is uncommon, and one, *Aulacophora similis* (Olivier), the orange pumpkin beetle, is a serious pest of several cucurbit crops including watermelon, cantaloupe, and cucumber. In Micronesia, this species is found in Palau, Yap, various atolls in the Western Carolines, and the Mariana Islands. It is present in South-East Asia and many other islands in the Pacific. In the Marianas, it was probably introduced sometime between 1946 and 1950.

Biology of the beetle. In life, in the Marianas the adult beetle is yellowish-brown on top and in Palau and Yap it is bright reddish orange. Underneath, it is black. The color difference suggests different source areas for the introductions to the Carolines and the Marianas as the beetles are the same species (Gressitt 1955). The adults feed on the leaves, flowers, and fruit of several species of cucurbits. On the leaves they frequently make semi-circular cuts before consuming the leaf material. These cuts are not made on flowers.

The round, yellow eggs are laid in the soil, predominantly in the upper three cm, but also in at deeper depths. In the laboratory, they will also lay their eggs on bits of the host plant. Other species of *Aulacophora* are known to lay their eggs on debris as well as in the soil (Waterhouse & Norris 1987). At 26°c the eggs hatch in 10 -14 days (average mean 11.5).

The larvae are cream colored or whitish, occasionally having a yellowish cast. They are elongated and worm-like with a brown head capsule, and a sclerotized caudal plate. The larvae feed on the roots and on parts of fruits touching the soil. Occasionally, they will tunnel up the inside of the stem and feed on the inner parts, or inside the petioles of the leaves.

Despite the importance of this insect as a pest, little is known about its development rates. In consequence, I have initiated some studies to provide information on its basic biology.

Materials and Methods

Development time. In the laboratory, larvae were reared on watermelon rind, and seedlings of corn, pechay, sweet potato, bittermelon (*Momordica charantia*), watermelon, pumpkin, and pepino to determine their suitability for growth and development. All larvae were reared on a 13 (light) :11 (dark) hour day at 25°C dark, and 27°C light. Larvae were reared individually in one ounce plastic cups. Food was supplied as needed. Larvae were checked daily to determine instar. Sand was placed in the bottom of the vial for the larvae to pupate in once they stopped feeding. Newly hatched first instar larvae were used in all trials.

Adult host plant preferences in the field. Adult host preferences were tested in the field by interplanting zucchini, honeydew, cantaloupe, watermelon, cucumber, pumpkin, bittermelon, luffa, and pepino. Each species was planted in hills five feet apart. Each hill consisted of three seeds arranged in a triangle with one foot between seeds. One hill of each plant type was planted in each row. The order of planting was randomized, and there were a total of ten rows. All rows were five feed apart. The field was planted April 23, 1990.

After the seeds sprouted, the number of beetles feeding on them were counted on May 7 and May 14. On May 23, 25 mature, full-sized leaves were collected from each type of plant. The number of accumulated feeding sites ascribed to orange pumpkin beetles was counted on each leaf.

Results and Discussion

Development time. All larvae died in the first instar within 2-3 days on corn, pechay, and sweet potato (Table 1). Larvae placed on these hosts did not feed and would not stay on the plant. On bittermelon, most of the larvae did not feed and died within two or three days, but a few did feed. These larvae survived five or six days, but still died as first instars. No evidence of growth or increase in size was noted.

Larvae developed on watermelon, pumpkin, watermelon rind, and pepino. On these hosts there were three larval instars. At each moult, the larvae left the host one or two days prior to moulting. In the third instar, the larvae fed for about half of the developmental period, and then quit feeding and constructed a cell in the sand. This cell was about 1.5 to 2 times the size of an adult beetle. The larvae then entered a quiescent prepupal period which lasted several days (Table 2).

Both watermelon seedlings and watermelon rind were equally suitable for growth, but development was faster on the seedlings (Table 2). On seedlings, the larvae ate the roots, stems, and leaves. First instars frequently tunnelled in the tap root and in the stems, behaviors also observed in the field. Development took 41 days and 37% of the larvae survived. On the rind, survival was slightly higher, 42%, but development was slower, particularly for the first and second instars. The third instar, the instar most commonly found on the melons in the field, developed equally rapidly on seedlings or rind.

On pumpkin, development from first instar to adult took 44 days, but survival was only 10%. On pepino, development took about the same amount of time as on watermelon seedlings, but only 20% of the larvae survived.

On watermelon seedlings, total development time from egg to adult was about 53 days.

Adult host plant preferences in the field. Zucchini attracted the most beetles followed by pumpkin, honeydew, and cantaloupe. Cucumber, pepino, luffa, and bittermelon were not as attractive in the seedling stage. Once the plants developed full-sized leaves, preferences shifted slightly with local pumpkin, zucchini, honeydew and cantaloupe the most favored. Cucumber, pepino, luffa, and watermelon continued to be less attractive hosts. Bittermelon never had any beetles on it (Table 3).

Zucchini had the most feeding sites followed by honeydew, cantaloupe, watermelon, cucumber, and pepino. Pumpkin had slightly less damage. Neither luffa, which consistently had a few beetles on it, or bittermelon, had any feeding damage. Bittermelon, one of the most common weeds in fields and along roadsides on Guam, is also unattractive to *Aulacophora foveicollis* (Waterhouse & Norris 1987), and is not a larval host.

Table 1. Survival of the orange pumpkin beetle on sweet potato, corn, pechay, and bittermelon.

Host	Number Replicates	% survival	Instar at death
Sweet Potato	20	0	1
Corn or Maize	20	0	1
Brassica (Pechay)	20	0	1
Mormordica charantia	20	0	1

Table 2. Survival and development of the orange pumpkin beetle on watermelon rind, and seedlings of watermelon, pumpkin, and pepino. Development time is reported in days.

Plant part	Development time for instars and stages							
	Instar							
	First	Second	Third			Pupa	Total development time	Percent survival
			Feeding	Prepupal	Total			
Watermelon rind	9.4	8.8	9.2	8.9	18.1	10.8	47.0	42
Watermelon seedling	6.4	7.1	8.1	9.9	17.4	10.7	41.6	37
Pumpkin	4.7	6.4	9.8	11.8	21.1	11.5	43.7	10
Pepino	6.8	6.1	8.8	8.3	17.2	10.5	38.8	20

I suspect that most of beetles infesting farm fields are coming from feral pumpkin or other farm fields. Beetles produced in fields abandoned after harvest is complete are probably a major source of new infestations. I recommend that farmers plow under fields immediately after harvest, or when they are abandoned for any reason. I also suggest farmers remove any wild pumpkin plants from their farms.

Acknowledgments

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Table 3. Number of beetles and amount of feeding damage on selected cucurbits.

Crop	Number of beetles per plant on		Feeding sites per leaf on
	May 7	May 14	May 23
bittermelon	0.0	0.0	0.0
luffa	0.3	0.2	0.0
local pumpkin	2.3	2.1	4.2
pepino	0.0	0.3	6.3
cucumber	0.3	0.5	6.4
watermelon	0.1	0.1	7.6
cantaloupe	0.6	0.9	8.5
honeydew	1.0	1.1	8.6
zucchini	8.7	1.9	39.6

CONTROL OF ORANGE PUMPKIN BEETLES IN WATERMELONS

ILSE SCHREINER and DONALD NAFUS

College of Agriculture and Life Sciences
University of Guam
Mangilao, Guam, 96923

ABSTRACT An experiment was planted in 1989 to assess soil and foliar treatments of *Aulacophora similis* on watermelon. The results showed that carbaryl was extremely effective at reducing the number of orange pumpkin beetles in the field. Half of the field was treated, and half of the field not. Control of the beetles in the treated plots also resulted in control of the beetles in the unsprayed plots, presumably because of the high mobility of the adult beetles. Foliar treatments with carbaryl were highly effective even when only small portions of the field were treated. A second experiment in 1990 showed that even treatment of one row out of every four resulted in a 96% reduction of beetle numbers early in the season and a 75% reduction late in the season when adults beetles were emerging within the field. Even treatment of only the two outside rows out of 14 resulted in a 65% reduction in adult beetle numbers.

In both experiments, the number of beetle larvae was higher in the plots treated with granular diazinon that in those receiving no soil insecticide. However the difference was not significant.

Beetles were non-randomly distributed in fields. Early in the season greater numbers were found on the larger plants, though this trend disappeared when the area covered by the plants increased. Locations of larvae under melons were significantly correlated with the location of adult beetles early in the season, but no correlation between these factors and overall damage to the bottoms of melons was observed. Beetles populations in 1989 were higher than in 1990, but fewer melons were damaged by beetle larvae in 1989.

Watermelons are the most valuable crop grown commercially on Guam. As high money producers, they are also consumers of a relatively heavy insecticide burden. Outbreaks of certain pests, such as *Thrips palmi*, may be caused by overuse use of insecticides. Because of these reasons, watermelon may be an appropriate crop for the development of IPM strategies. An IPM program for watermelon has been developed for Hawaii (Johnson et al. 1989), where many of the same pests occur. Under ADAP funding, this IPM program was tested on Guam in 1990. One problem which has faced the program is that there are several pests of cucurbit crops present on Guam that are not found in Hawaii. These include the orange pumpkin beetle *Aulacophora similis*, the Asian melon worm, *Diaphania indica*, and the cluster caterpillar *Spodoptera litura*. Relatively little information about the effects of any of these organisms is available, especially in watermelon. Little is known about the biology of *Aulacophora similis* in general (Waterhouse and Norris 1987). The adults of this beetle feed on the foliage and flowers of a variety of cucurbit plants including watermelons, and the larvae feed on the roots and the undersides of the fruit where they are in contact with the soil.

On Guam, several projects to identify some of the parameters necessary to integrate the control of the orange pumpkin beetle into the watermelon IPM system developed for Hawaii are being implemented. Two experiments were recently undertaken to determine what insecticides were capable of controlling the beetles, and to obtain any other information about beetle biology as could be noted.

Materials and Methods

An experiment was begun in January 1989 to test the efficacy of foliar sprays of carbaryl (2 Tb/gallon) for the control of orange pumpkin beetle adults and the effectiveness of a soil insecticide (granular diazinon 4 lbs A.I./acre) for the control of the larvae. The experiment was run in a split plot design with the main plots being the foliar insecticide treatment and the subplots being treated with granular diazinon or not. The plot size was seven rows, five feet apart and 20 feet long. The foliar insecticide was applied three times during the season when populations of beetles were high. In a second trial planted in January 1990, plots were either treated or not treated with granular diazinon. There were four replicates of each experimental treatment. Instead of spraying individual plots with foliar insecticide, selected whole rows were treated with carbaryl whenever adult beetle populations were high. On the first and third spray episode, every fourth row was treated. On the second spray, only the two outside rows (2 out of 14 rows) were treated. In both years the experiments were planted in Barrigada, Guam, on a heavy clay soil.

Results

Effect of foliar insecticide on adult beetle populations. When the data from the first experiment were examined, it was noted that even the relatively large plots used in the experiment were not big enough. No differences could be observed between the number of beetles in the treated an untreated plots even on the day after the plots were sprayed (Table 1). However, this does not imply that the insecticide did not work. Beetle counts for the whole field done the day before and the day after the spray were compared, and a dramatic reduction in the number of beetles in the whole field could be observed (Figure 1). The reduction in adult beetle numbers was 96% after the first spray, 90% after the second spray but only 66% after the third spray. The latter occurred sufficiently late in the season that beetles were emerging within the field, whereas earlier the beetles had all been immigrants. The reduction lasted about one week, but by the second week effects could no longer be seen. We conclude that the adult beetles are so mobile that spraying only half of the plots was sufficient to reduce the beetle population in the whole field.

Since partial treatment of fields seemed effective, the second experiment was used to determine just how little insecticide was necessary to control these beetles. Treating every fourth row was as effective in reducing adult beetle populations as was treating half the area. On the first occasion, spraying one row out of every four reduced beetle populations 96% (Figure 2). The second time one out of four rows were treated, there was only a 75% reduction in beetle numbers, but as with the less effective spray in 1989, this was late in the season when beetles were emerging within the field. Spraying only one row in seven did reduce the beetle numbers, but only by 65% and was obviously not sufficiently effective to be used as a method of controlling beetles in the whole field. As discussed below, beetles tend to be aggregated in certain parts of the field. It is probable that spray treatments could be concentrated in those areas and as long as one quarter to one half of the field were treated, even beetles that were not part of the aggregations at the time of spraying would be likely to be killed as they moved around the field.

Effects of the soil insecticide on beetle larvae populations. Beetle larval populations were counted by lifting fruits that were at least 10 cm in diameter, and counting how many larvae were visible under the fruits.

In the first experiment, the larvae were not randomly distributed in the field and were only found in five of the eight plots in the first sample taken Mar 10. In the second sample, taken Mar 17, only 1 immature beetle was found. In the Mar 10 sample, immature beetles were only abundant in three of the the plots, one treated with carbaryl and two untreated ones. For the three plots where beetles were abundant, the average number of larvae in the subplots treated with diazinon was considerably higher than the number in the subplots with no soil insecticide treatment (15.3 vs 2.7). The difference was not significant when the whole data set was analyzed because of the high variance between plots (Table 2).

Figure 1. Populations of adult orange pumpkin beetles in Experiment 1.

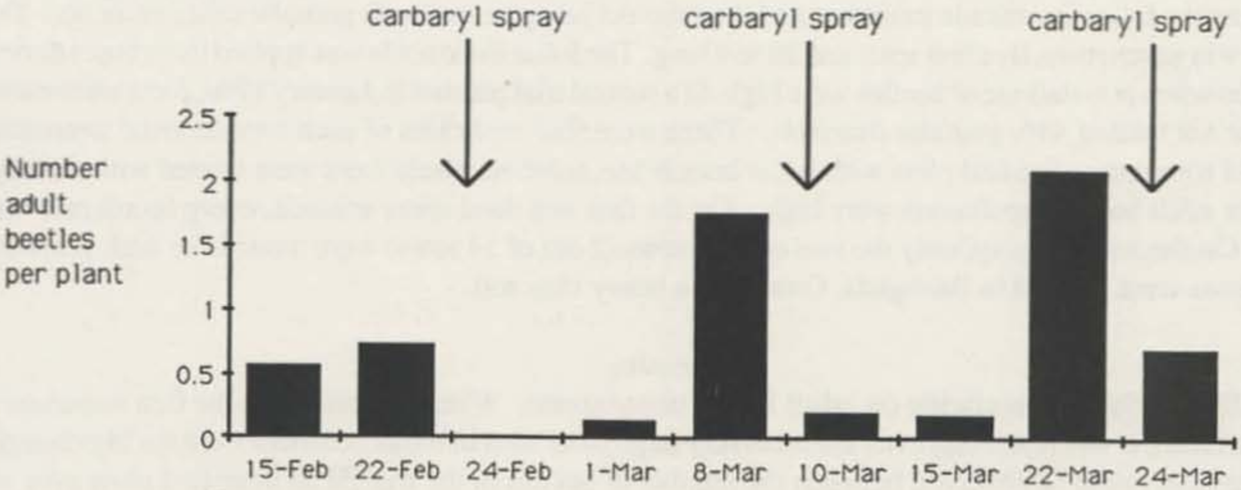

Figure 2. Populations of adult orange pumpkin beetles in Experiment 2.

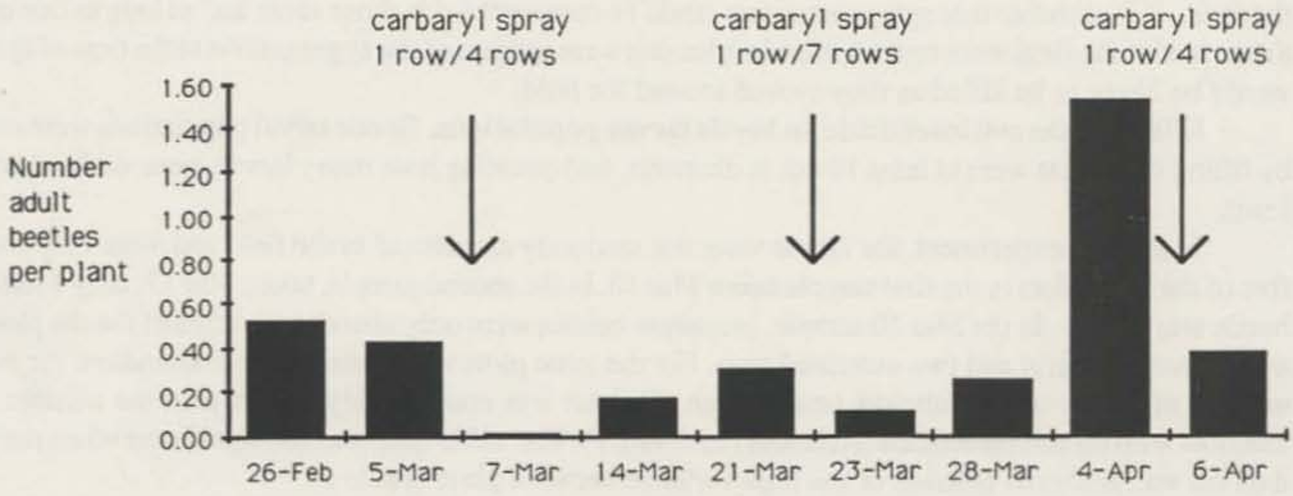

Table 1. Comparison of adult beetle numbers in treated and untreated plots one day after spraying.

Treatment	Feb 24	Mar 10	Mar 24
Carbaryl + Diazinon preplant	0.25	0.75	0.0
Carbaryl	0.0	0.25	0.0
Diazinon preplant	0.25	1.5	5.25
Check	0.0	1.0	6.25
F foliar treatment	0.00 n.s.	1.59 n.s	1.90 n.s
F soil treatment	2.00 n.s.	0.35 n.s	0.06 n.s

Table 2. Comparison of the number of larvae and damaged melons in treated and untreated plots.

Treatment	Number larvae	Percent of fruit damaged by larvae
Carbaryl + Diazinon preplant	1.25	10
Carbaryl	2.5	13
Diazinon preplant	10.75	15
Check	0.25	13
F foliar treatment	1.66 n.s.	0.31 n.s
F soil treatment	2.93 n.s.	0.0 n.s.

The number of watermelons damaged by larval beetles was not significantly affected by the soil or the foliar treatments (Table 2). A large number of melons were stolen from the first experiment before they could be examined, so we cannot be certain the data analyzed is unbiased. However, the larval damage did not penetrate the rind very deeply, so that there was no spoilage of fruit due to beetle damage. Damaged melons are readily purchased by consumers in the grocery stores and it is probable that damaged melons were as likely to be stolen as undamaged ones. Although the local people will buy melons with surface damage, hotels are unwilling to do so, so the damage does limit the market to some extent.

In the second experiment there were twice as many beetles in the plots treated with diazinon (an average of 7 under 20 melons searched per plot) as in those plots which were not treated (3.75 per 20 melons), however, the difference was not significant. No difference in the proportion of fruit damaged by beetle larvae could be observed.

One factor which significantly affected larval numbers was whether the melon was lying on the plastic mulch or not. Only one larvae was found under a melon lying on the plastic mulch, whereas all the rest of the larvae were found under melons lying on soil. Melons were three times more likely to be damaged if they were lying on soil than if they were lying on plastic. Some melons on plastic were damaged on the bottom, but this might have been due to melon worms that crawled under them. Where labor is not a limiting factor, much damage to the bottoms of the fruit could be avoided by placing something, perhaps a paper plate, between each melon and the soil.

Biology of the beetles in the watermelon crop. Adult beetles are easily seen on the leaves and can be readily counted as one walks down the row, making sampling these insects a simple job. In our sampling scheme, we counted the beetles visible on the plants, and then shook up the plants to agitate the beetles that were under the leaves. Disturbed beetles flew up and away from the plant. The proportion that was readily visible decreased as the season progressed and the plants became bushier. Initially about half the beetles were visible on top of the leaves, but later in the season only one third could be easily seen. Over all the sample dates, 40% of the beetles were evident on the plant, and 60% only appeared when the plant was shaken.

Adults tended to aggregate on all sample dates. Early in the season the aggregations were partly accounted for by the tendency of beetles to prefer larger plants. This tendency decreased as the plants grew larger, and disappeared when the average individual plant in the field became larger than 1/3 m^2. Late in the season as the plants died back, the tendency of beetles to be more abundant on larger plants was again noted.

The early season population of adults could be used to some extent to predict where the larval beetles would be found a month later when the undersides of melons were lifted. In 1989 there was a statistically significant, and in 1990, a 90% probability that there was a linear relationship between which plots had large numbers of beetles early in the season and which plots had many larvae under the fruits a month later. However, the location of melons with damage to the underside was much more evenly distributed around the field than was the location of larvae. The damage incidence could not be predicted from the location of adults early in the season. The relationship between adult beetle numbers and damage is obviously complex as there were twice as many beetles per plant in 1989 as in 1990, but in 1989 only 15% of the melons had damage on the bottom surface whereas in 1990, 75% did. Experiments with *Aulacophora foveicollis* have shown that when the soil is saturated with water, larvae are forced to the surface and then feed on fruit in contact with the ground (Melamed-Madjar 1960). It is likely that soil moisture levels also influence the probability that melons will be damaged by *A. similis* larvae.

Damage to the tops and sides of the watermelons. In these experiments which were only being occasionally treated, there was a considerable amount of scraping damage to the surface of the top and sides of the watermelons. Before these experiments, this damage was attributed to feeding by adult beetles. In the 1990 experiment, all insects noted as feeding on the surface of the melons were recorded. Only on one occasion was an adult beetle seen damaging the fruit. Much more common were larvae of the Asian melon worm *Diaphania indica* and cluster caterpillar *Spodoptera litura*. Occasionally, larvae of the green garden looper, *Chrysodeixis eriosoma,* were also observed feeding on the fruits. These caterpillars are often under leaves that are touching the melons, and are in general very much less conspicuous than the beetle adults. Beetle adults do sometimes cause widespread surface damage to the fruit, as this was observed in another field where beetles were very abundant. However, in general, it appears that the complex of Lepidoptera feeding in watermelon fields is more important in causing scraping damage to the tops of the watermelons than are adult beetle.

Impact of the beetles on the watermelon yield. In setting up this study, we hoped to gain information as to how the the adult and larval beetle populations affected yield. Unfortunately, due to the high dispersal abilities of the adults, this was not possible. However, observation of the field suggested that beetle adults probably do not have a significant effect on watermelon plants after the plants gain three or four leaves, unless huge numbers of beetles are present. Adult damage to large plants, though noticeable, does not generally involve large proportions of the leaf tissue. Huge numbers of adult beetles are likely to be seen only when the crop is maturing and beetles that have bred within the field are emerging. At that time it is unlikely that the beetles will damage the planting. Of course, if a new planting is nearby, the latter may be seriously damaged by the adults dispersing from the old field if these are not controlled. We do not yet know what the impact of larval feeding on yield might be. The larvae not only feed on the bottom side of the fruit as discussed but also on the roots of the plants. In the future, we hope to identify larvicides more effective than diazinon, and to use these to assess the impact of larval feeding on melon yield.

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DECISION MODEL AND DATABASE FOR MANAGEMENT OF WATERMELON PESTS IN GUAM

AUBREY MOORE, MARSHALL W. JOHNSON[1] AND LEE S. YUDIN[2]

Land Grant Program, Northern Marianas College, Saipan, MP 96950

ABSTRACT A primary goal of the Guam watermelon integrated pest management program is to reduce unnecessary pesticide applications by recommending treatment only when pest populations exceed action thresholds (population levels expected to cause significant damage). These thresholds vary with crop stage, level of biological control, and other field conditions.

To facilitate calculation of action thresholds, we have developed a database system which stores pest survey data, calculates thresholds, and prints reports which are given to each grower. Reports include current pest levels, field conditions, control recommendations, and a history of pesticide applications for each field.

This system uses an inexpensive software package (Reflex 2.0, Borland International). Ease of use and modification were primary design considerations. This database will be useful for evaluation and refinement of the Guam watermelon IPM program.

A major objective of the ADAP Crop Protection Project is to promote the use of integrated pest management (IPM) in the Pacific Islands. Expected benefits are a reduction in unnecessary pesticide use, increased biological control of pest populations, and a decrease in the development of pesticide resistance.

This report describes a computerized data processing system which was developed to facilitate implementation of IPM for watermelon production in Guam. The Guam watermelon IPM program is based on a similar program developed in Hawaii (Johnson et al., unpublished). At the core of this program is a decision model which generates pest control recommendations based on data collected by crop monitoring (Figure 1).

Overview of the Guam Watermelon IPM program

Crop monitoring. The health of watermelon plantings is assessed by weekly inspections. Most insect population estimates (for leafminer larvae, leafminer parasites, thrips, alate aphids, apterous aphids) are based on counts on 20 leaves which are taken back to the laboratory. The proportion of vine tips infested with thrips is estimated in the field from a sample of 50 tips. Population density of orange pumpkin beetles is determined from the number of adults seen on 20 plants.

[1]Department of Entomology, University of Hawaii, Manoa, Honolulu, HI 96822
[2]Cooperative Extension Service, University of Guam, Mangilao, Guam 96923

Table 1. Crop stage index (CSI) for watermelon

Phenological benchmarks	Index
Seed	0.0
Germination	1.0
10-inch vine	2.0
First flowers	3.0
First fruit set	4.0
Softball size fruit	5.0
Harvest begins	6.0
Harvest ends	7.0
Crop stages used in leafminer and aphid decision models	
'Small plants'	≤ 2.0
'Plants 2 to 8 weeks old'	2.0 to 6.0
'Full foliage canopy, near harvest'	≤ 5.0
'Harvest started'	≤ 6.0
Crop stages used in thrips decision model	
'Plants less than 3 weeks old'	<2.5
'Harvest near completion'	>6.5

FIGURE 1. System diagram for the Guam watermelon IPM program

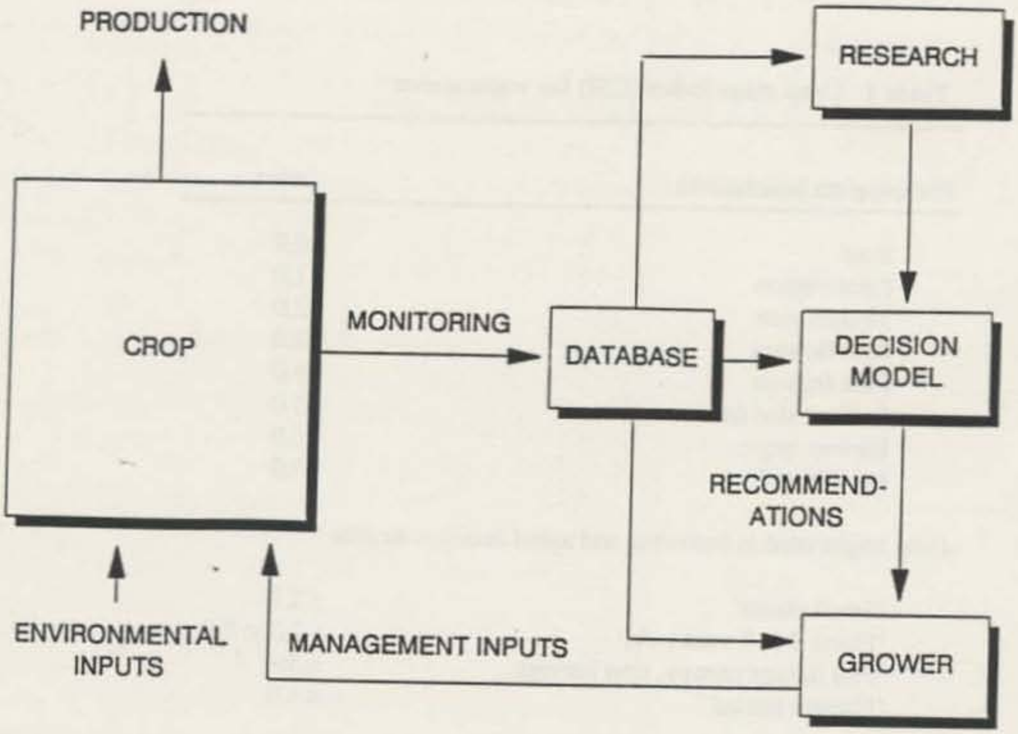
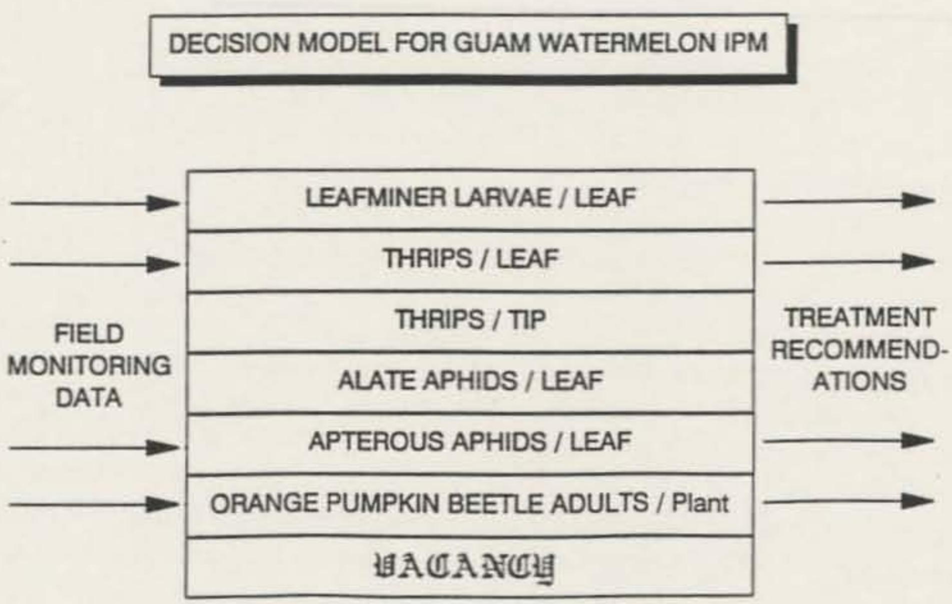


FIGURE 2. Decision model components for pests currently monitored by the Guam watermelon IPM program



Plant phenology is recorded as a crop stage index (CSI). This index is a real number ranging from zero to seven and is based on a well defined phenological benchmarks (Table 1). In the original decision model, some action thresholds were a function of crop age measured chronologically rather than phenologically. In these cases, we chose what we feel are appropriate values of CSI (Table 1). We feel that measuring the development of a crop in terms of phenology is preferable because growth rates vary with environmental variables (soil moisture, temperature, solar radiation, soil fertility) and biological variables (cultivars, pest impact, disease).

Miscellaneous observations are also recorded in the field notes.

Decision model. The decision model consists of several discrete components; one for each of the major pests currently being monitored (Figure 2). Within each component, the current pest abundance estimated from field sampling is compared to an action threshold. An action threshold is the pest abundance level at which control must be initiated to avert economic loss. If this threshold is exceeded, treatment is recommended.

Action thresholds are typically dynamic, varying with factors such as crop stage, abundance of biological control agents, presence of plant disease, and previous pest population level.

Status reports. Two reports are generated for each field being monitored: a pest survey report and a field history report. Treatment recommendations are communicated by telephone within 24 hours. The pest survey report (Figure 3) describes current field conditions. The current population density and action thresholds for each major pest are presented. Pest situations requiring immediate treatment are flagged. The report includes a treatment recommendation, and miscellaneous field observations. The field history report (Figure 4) contains a chronology of management activities for each field being monitored including population levels of major pests, treatment recommendations, pesticide applications, and miscellaneous field observations.

Data processing for the Guam watermelon IPM prgram

Database design. The Guam watermelon IPM database was implemented using Reflex 2.0 (Borland International). This package was chosen for ease of use, quality of documentation, and reasonable cost ($50, educational discount price). Reflex allows the user to examine and manipulate data using four different 'views': List View, Form View, Graph View, and Report View. Here we will only be concerned with use of the List View which is very similar to a spreadsheet presentation of the data, and the Report View, which is used to design and generate reports.

When displayed using the 'List View', data stored by Reflex is organized like a two dimensional spreadsheet. Each cell contains a number, text, or a function. Each row of cells is a record. Each column of cells is a field. Table 1 shows all the fields that are currently in the database. A new record is added to the database for each pest survey. Some of the fields contain formulas which automatically calculate values based on data in other database fields.

The 'Report View' facilitates design and modification of printed reports. Several report formats, each tailored for a different purpose, can be associated with a Reflex database. Two report formats have been designed for the Guam watermelon IPM database: a pest survey report and a field history report.

Automatic calculation of action thresholds. We will use the action threshold for orange pumpkin beetles as an example of how action thresholds are calculated. The orange pumpkin beetle is a major pest of watermelons and other cucurbits in Guam. It does not occur in Hawaii. The adult beetles eat large amounts of foliage and larvae attack the roots. In the present IPM program, population estimates in units of number of beetles per plant are estimated by counting adults on 20 plants in each field being monitored. Research is underway to determine the biological and economic impact of this pest on cucurbit production (Nafùs and Schreiner, unpublished data). Until this work is completed, an ad hoc action threshold has been

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GUAM WATERMELON IPM PROGRAM - PEST SURVEY REPORT  [pestsurv.r2r]

Grower: Juan Doe, Toto, 999-9999
 Field: JD90-1 IPM SECTOR
  Date:  5/23/90

RECOMMENDATION:

   TREATMENT FOR THRIPS IS NECESSARY

NOTES:

   No beneficial insects seen;  moderate beetle damage on
   some plants

CSI = crop stage index ......................................     5.2
-----------------------
0.0  Seed               4.0  First fruit set
1.0  Germination        5.0  Softball size fruit
2.0  10-inch vine       6.0  Harvest begins
3.0  First flowers      7.0  Harvest ends

PEST                                                ACTION      CURRENT
CODE                                                 LEVEL        LEVEL
----                                               -------       ------

BTL = orange pumpkin beetles per plant .........      0.10         0.05

MOS = % of plants with mosaic virus symptoms ...                      1

AP1 = wingless aphids per leaf .................                   4.80
AP2 = winged aphids per leaf ...................      0.00         0.00
APH = total aphids per leaf ....................     35.00         4.80
ANE = adequate natural enemies for aphids ......                      Y

THR = thrips per leaf ..........................      8.00         1.85
TIP = % of vine tips infested with thrips ......        20           34 ***

CAT = caterpillars per leaf ....................                   0.00

LMN = leafminers per leaf ......................     35.00         0.00
PAR = leafminer parasites per leaf .............                   0.00
LMNS= adequate leafminer parasites .............                      Y

ANT = ants per leaf ............................                   0.00

Thank you for cooperating in the Guam Watermelon IPM Project.
If you have any questions, please contact Dr. Aubrey Moore
at 734-2518 (UoG) or 477-1297 (home).
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FIGURE 3. Pest Survey Report

Guam Watermelon IPM Program - Field History Report [fldhist.r2r]

Grower: Juan Doe, Toto, 999-9999
Field: JD90-1 IPM SECTOR

Date	Activity	CSI	BTL	MOS	AP1	AP2	APH	THR	TIP	CAT	LMN	PAR	ANT
3/19/90	SEEDED Top Yield, Not irrigated												
4/25/90	PEST SURVEY No beneficial insects seen; moderate beetle damage on some plants TREATMENT FOR PUMPKIN BEETLES is necessary	3.5	0.45	0	0.10	0.00	0.10	0.45	5	0.00	0.00	0.00	0.05
5/02/90	PEST SURVEY Moderate beetle damage to leaves; No beneficial insects seen; TREATMENT FOR PUMPKIN BEETLES is necessary	3.8	5.90	0	0.35	0.05	0.40	0.05	12	0.00	0.00	0.00	0.05
5/09/90	PEST SURVEY Weeds plowed under on previous day; No beneficial insects seen; TREATMENT FOR PUMPKIN BEETLES is necessary. (Low beetle counts during survey probably due to disturbance when weeds were plowed under)	4.0	0.05	0	0.20	0.00	0.20	0.05	2	0.00	0.00	0.00	0.00
5/09/90	SPRAY Pounce (fenvalerate); sprayed after pest survey												
5/16/90	PEST SURVEY Some plants dying; possibly due to root disturbance when field was plowed; Beneficial insects: predatory wasp TREATMENT FOR BEETLES IS NECESSARY. The beetles hide in the long grass along the bottom edge of the field. If you spray this grass, and the first row of melons with Sevin, this should take care of this localized problem.	5.4	0.40	10	0.20	0.00	0.20	0.70	2	0.00	0.00	0.00	0.00
5/23/90	PEST SURVEY No beneficial insects seen; moderate beetle damage on some plants TREATMENT FOR THRIPS IS NECESSARY	5.2	0.05	1	4.80	0.00	4.80	1.85	34	0.00	0.00	0.00	0.00

Number of sprays to date = 1

FIGURE 4. Field History Report

established: until harvest begins, insecticide treatment will be recommended when there are more than 0.1 beetles per plant in the field sample; after harvest begins, treatment is recommended if there are more than 2 beetles per plant (Figure 5).

Figure 6 shows how Reflex is programmed to determine the current action threshold and whether or not treatment is required. We can check to see if harvest has begun using the data stored in the CSI field. Harvest begins when the crop stage index is 6.0. The current action threshold for beetles is calculated automatically using a formula stored in the MaxBTL field:

@IF(CSI<6, 0.1, 2.0).

In plain English this means: if the harvest has not begun (crop stage index less than 6.0) then the action threshold is 0.1 beetles per plant, otherwise the action threshold is 2.0. When a pest status report is printed the current beetle level and action threshold are shown. If treatment is necessary, a flag, '***', is printed next to the current beetle population level. The formula stored in the pest status report design is:

@IF(BTL>MaxBTL, '***', ' ').

Discussion

In addition to automating the generation of reports that advise growers on managing pest situations as they arise, information accumulated in the database may be used for evaluation and further development of the Guam watermelon-IPM program. Reflex provides many software tools which facilitate data reduction, statistical analysis, crosstabulation, and graphical representation. 'What if' analysis is also possible. For example, we can readily evaluate the effect of changes made to the decision model by modifying the formulas which calculate action thresholds. New fields can be added to the database to reflect additional pests being monitored, or the adoption of new sampling techniques.

Although we developed the Guam watermelon IPM database using Reflex 2.0, our methodology could be implemented using a number of popular spreadsheet and database programs. One disadvantage of Reflex 2.0 is that its use is limited to IBM compatible equipment. Implementation using Excel might be desirable as this is one of the few packages with versions available for both IBM and Apple equipment.

The methodology we have developed for handling data collected by the Guam watermelon IPM program is flexible and can be readily adapted to facilitate implementation of IPM aimed at managing ensembles of pests in other crops and at other locations.

References cited

Johnson, Marshall W., Albert P. Martinez, Ken Y. Takeda and Steve Fukuda 1984. Watermelon integrated pest management implementation program in Hawaii. Unpublished report.

FIGURE 5. Action threshold for the orange pumpkin beetle. Treatment is recommended when the number of beetles per plant (BTK) exceeds the threshold (MaxBTL)

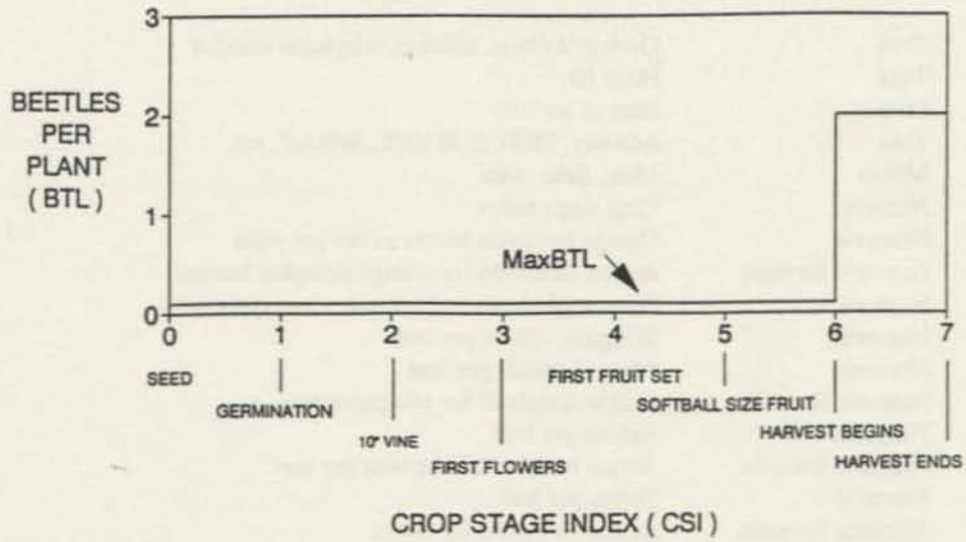
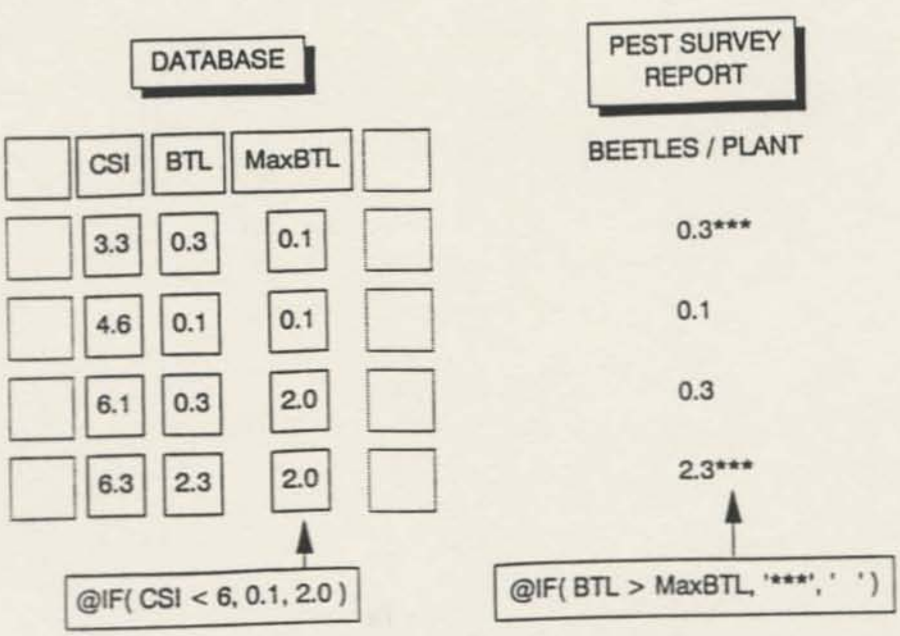


FIGURE 6. Decision model component for orange pumpkin beetle implemented as formulas in a Reflex 2 database. Refer to text for explanation.



Appendix 1. List of fields in the Guam watermelon IPM database.

Database Field	Type	Description
Grower	Text	Grower's name, address, telephone number
Field	Text	Field ID
Date	Date	Date of activity
Activity	Text	Activity: PEST SURVEY, SPRAY, etc.
Notes	Memo	Misc. field notes
CSI	Numeric	Crop stage index
BTL	Numeric	Orange pumpkin beetle adults per plant
maxBTL	Numeric formula	Action threshold for orange pumpkin beetles
MOS	Numeric	Percent of plants with mosaic virus symptoms
AP1	Numeric	Wingless aphids per leaf
AP2	Numeric	Winged aphids per leaf
maxAP2	Numeric formula	Action threshold for winged aphids
APH	Numeric	Aphids per leaf
maxAPH	Numeric formula	Action threshold for aphids per leaf
THR	Numeric	Thrips per leaf
maxTHR	Numeric formula	Action threshold for thrips
TIP	Numeric	Percent of vine tips infested with thrips
maxTIP	Numeric formula	Action threshold for vine tips infested
CAT	Numeric	Caterpillars per leaf
LMN	Numeric	Leafminer larvae per leaf
LMNL	Numeric	Leafminer larvae per leaf at last sample
maxLMN	Numeric formula	Action threshold leafminer larvae per leaf
PAR	Numeric	Leafminer parasites per leaf
ANT	Numeric	Ants per leaf
RECOMMEND	Memo	Treatment recommendations
LMNS	Text formula	Leafminer situation stable?: Y/N
ANE	Text	Adequate natural enemies?: Y/N

CONTROL OF THE LEAF-FOOTED BUG ON CUCUMBER BY NON-TRELLISING

NELSON M. ESGUERRA, WILLIAM S. WILLIAM AND JUSTINO R. SMITH

Land-Grant Program, College of Micronesia
Pohnpei, FSM

ABSTRACT The insect pests that attacked cucumber were, in decreasing order of importance, leaf-footed bug, melon aphid, green garden looper, green stink bug and pumpkin caterpillar. The leaf-footed plant bug started to infest the crop at flowering time and persisted in high number up to the last harvesting period.

The leaf-footed plant bug preferred to attack trellised cucumbers. No bugs were encountered on those cucumbers crawling on the ground on top of mulch. One probable reason was ambient temperature, the daytime temperature being more than 3°C higher on cucumbers crawling on the ground on top of mulch. The other probable reason was that ground lizards played a role in discouraging bugs from alighting on the crawling cucumbers.

The experiment proved that control of the leaf-footed plant bug could be accomplished by cultural means. If a variety of cucumber is developed to crawl on the ground and is available to local growers, the leaf-footed bug would not be a problem pest.

The leaf-footed plant bug, *Leptoglossus australis* (F.), is an important insect pest of cucurbits on Pohnpei, Federated States of Micronesia. This pest has never been recorded as a pest of cucurbits in the other FSM states, although it is present on Guam. Both nymph and adult bug suck the sap from flowers, leaves and developing fruits of cucurbits. Newly developed fruits become deformed, thus lowering their commercial value. Damaged flowers fall off.

On cucumbers which are normally allowed to climb on trellis, farmers always complain of high numbers of this bug especially from flowering to harvesting stages of the plant. On squash and other cucurbits that crawl on the ground, the pest is seldom encountered. The reasons why these bugs showed prefer to attack trellised cucumbers is not known.

Experiments were conducted with the following objectives:

1. document the preference of the leaf-footed bug for attacking trellised cucumbers only, and
2. attempt to find out the reasons for the bugs non-preference for cucumbers crawling on the ground.

Materials and Methods

Experiment I. Seeds of Tasty Green, F1 hybrid of Cucumber, were planted in all experimental plots. Fertilizer application, hand weeding and other cultural practices were followed to insure good growth of plants.

The treatments were: A) cucumbers allowed to climb on vertical trellis, B) cucumbers allowed to climb on Teepee trellis and, C) cucumbers that crawled on the ground on top of mulch.

Each treatment consisted of one row of cucumbers for treatment A, 2 rows of cucumber for treatment B and 1 row of cucumbers for treatment C. Rows averaged 24 plants. Each treatment was replicated five times in a Randomized Complete Block Design. For treatments A and B, cucumber nets were provided on those trellises for the plants to climb. Two to three weeks after emergence, the seedlings were trained to climb on trellises. For treatment C, thick mulches which consisted of grasses and vines were put on rows and plants were allowed to crawl on top of the mulch. Mulch was provided to prevent fruits from touching the ground and therefore escape being attacked by soil-borne rotting microorganisms.

Leaf-footed bug counts were done three times during the growing season. Bug counts were made during early morning hours when they were less active and could be readily counted.

Since the variety used in both experiments was a trellised variety, yield data were not taken because very few fruits developed on those vines crawling on the ground.

Experiment II. The experiment was conducted at two sites: one at a farmers' field where the leaf-footed plant bug occurred every growing season, and the other one at the experiment station where the bugs were also established. Two thermometers were installed, one on the trellised plot and the other one on the mulch where cucumbers were crawling. Temperature reading was done in the morning (7:30 am) at 12:00 noon and at 4:30 PM each day throughout the growing period of the plants.

The experiment at the farmer's field consisted of 9 rows planted to cucumber. Each treatment had 10 plants and was replicated 4 times in a Randomized Complete Block Design. The treatments were the same as in Experiment I.

Counts of leaf-footed bugs were done once at peak harvest. Melon aphid, *Aphis gossypii*, infestation was determined once during growing season.

Results and Discussion

Insect Pests Observed. Aside from the leaf-footed plant bug, other insect pests were observed attacking cucumbers from planting to harvesting periods of the plants. The black garden fleahopper *Halticus tibialis* infested cucumber during the seedling stage, producing small whitish spots on upper surfaces of leaves. The damage became less noticeable during the later stages of plant growth.

The melon aphid began to appear as soon as the plants climbed on the trellis. Infestations were also noticeable on plants crawling on the ground. Affected cucumber leaves curled and had aphids on under surfaces of leaves.

The green stink bug *Nezara viridula* was noticeable during the flowering and fruiting stages of the plant. Both nymphs and adults suck the sap from developing fruits, leaves and stems of cucumber. These bugs also attacked trellised cucumber only.

The pumpkin caterpillar, *Diaphania indica* Saunders, was noticed on trellised cucumber. The larvae feed on leaf edges. The larvae, however, caused only minor damage to plantings.

Experiment I. Infestations of the leaf-footed bug usually started when the cucumber plants began to climb on trellises or at flowering time. However, in this experiment the bug appeared late in the growing season. Low populations of the bug appeared during the second harvest. Populations became high when the plants were about to be knocked down. Based on three counts, those cucumbers on vertical trellis had 7.4, 59.2 and 118.4 bugs/row in the first, second and third counts respectively; while those on teepee trellis had counts of 6.4, 30.4 and 195.4 bugs per row. No leaf footed bugs were observed on cucumbers crawling on the ground (Table 1). These results confirmed our earlier observation that only cucurbits growing on trellises were attacked by the pest.

Experiment II. Since the leaf-footed bugs appeared late during the growing season in Experiment I, a similar experiment was set up, one in farmers' field where the bug was known to occur every growing

Table 1. Effect of the types of trellis on the number of leaf-footed plant bug

Treatment	Number of leaf footed bugs		
	1st Count	2nd Count	3rd Count
Cucumber on Vertical Trellis	7.4	59.2	118.4
Cucumber on Teepee Trellis	6.4	30.4	195.4
Cucumber crawling on the ground	0	0	0

Table 2. Effect of types of trellis and temperature on the population of leaf footed plant bug and on melon aphid infestation (Experiment Station).

Treatments	Time of day	Temperature Reading	Melon aphid infestation [1]	Number of leaf-footed bugs
Cucumbers on Vertical trellis	Morning Noon Afternoon	27.2 29.6 29.0	0.6	23.6
Cucumber on teepee trellis			0.7	19.4
Cucumbers crawling on the ground	Morning Noon Afternoon	27.4 32.2 32.6	0	0

[1] Index of infestation: 0 - no aphid infestation, 1 - 1-25 aphids/leaf in each plant, 2 - 26-50 aphids/leaf in each plant, 3 - 51-75 aphids/leaf on each plant, 4 - 76-100 aphids/leaf on each plant

Table 3 Effect of types of trellis on the population of the leaf-footed plant bug (Farmers' Field)

Treatments	Number of leaf-footed bugs
Cucumber on Vertical Trellis	26.8
Cucumber on Teepee Trellis	29
Cucumber crawling on the ground	0

season and the other one at the Experiment Station where bugs were already established.

At the Experiment Station at peak harvest, each row had an average of 23.6 bugs and 19.4 bugs on cucumbers on vertical and teepee trellises respectively. Again, no leaf-footed bugs were encountered on those cucumbers crawling on the ground (Table 2). The temperature throughout the growing period was higher on those cucumbers crawling on the ground on top of mulch than on trellised cucumbers. Noon and evening temperatures were 3°C higher on the ground than on the trellis. It was possible that leaf-footed bugs could not withstand the higher temperature on the ground, hence, trellised cucumbers were preferred by the pest. It was further observed that any leaf-footed bug that accidentally alighted on those crawling on the ground had to fly immediately to avoid being preyed upon by ground lizards.

In farmers' field, there were 26.8 leaf footed bugs on cucumbers climbing on vertical trellis and 29 on those cucumbers climbing on teepee trellis. Leaf-footed bugs were absent on those cucumbers crawling on the ground (Table 3).

Clearly, the leaf-footed bugs preferred to attack trellised cucumbers and those plants can escape from their infestation if they are allowed to crawl on the ground. Unfortunately, the variety used was not a variety that was meant to crawl on the ground. Thus few fruits developed on those cucumbers crawling on the ground.

Since non-trellised variety of cucumber is unavailable to the islanders for use or that kind of variety has yet to be developed elsewhere, other methods of control must be devised against the leaf-footed bug.

In November 1989, the COM Land Grant Programs received shipments of the parasitized eggs of the green stink bug, *Nezara viridula*. The wasp parasites that emerged, *Trissolcus basalis*, were released around Kolonia and at the Pohnpei Agriculture and Trade School primarily to control the stink bugs. These parasites may also attack the eggs of the leaf-footed bugs. Other host eggs of the parasites will be studied and monitored in the farmers' fields.

IMPACT OF STYLET OIL, REFLECTIVE MULCH AND APHICIDES ON SPREAD ON NONPERSISTANTLY TRANSMITTED VIRUSES IN CUCURBITS

DIANE ULLMAN

Department of Entomology, University of Hawaii, Honolulu, HI 96822

ABSTRACT Epidemics of aphid transmitted viruses represent one of the most difficult problems cucurbit growers in the tropics have to face. Management of these viral epidemics is complicated by the fact that acquisition and transmission can occur in seconds to minutes following landing of winged aphids on plants. Furthermore, noncolonizing, transient aphid species are often the most important vectors.

The impact of stylet oil, reflective mulch and Orthene (an aphidicide) on virus incidence and yield in zucchini was assessed in field plots in the island of Maui. The results show that in warm, dry conditions stylet oil can reduce virus incidence. Yield did not differ significantly from untreated controls. In contrast, reflective mulch was very effective in reducing virus incidence and increasing yields under cool, wet conditions. Orthene was effective in controlling the only colonizing aphid vector species, the melon aphid, *Aphis gossypii*, yet, when compared to untreated controls, virus incidence increased two fold in Orthene treated plots with a concomitant decrease in marketable yield.

These results suggest that growers may reduce epidemics of aphid transmitted viruses by using stylet oil and reflective mulch in their cucurbit plantings. These techniques do not impact the natural enemy complexes so important to biological control of other pest problems and are environmentally sound. Seasonal variation in temperature and precipitation should be considered when choosing between these control measures. The results obtained the Orthene treated plots indicated that treatment with aphidicides exacerbates virus problems without any economic benefit to the grower. The significance of these results as they apply to integrated pest management programs in cucurbits was discussed.

OCCURRENCE AND CHARACTERIZATION OF A VIRUS INFECTING YARD-LONG BEAN (*VIGNA UNGUICULATA* SUBSP. *SESQUIPEDALIS*) ON GUAM

C. A. KIMMONS, G. C. WALL, D. A. NELSON AND B. B. REDDICK[1]

CALS/AES, University of Guam, Mangilao, GU 96923

ABSTRACT A virus causing mosaic disease of *Vigna unguiculata* subsp. *sesquipedalis* (yard-long bean) on Guam was isolated and partially characterized. Systemically-infected bean plants develop mosaic, dark-green vein-banding and leaf distortion. In host-range tests, 49 plant species, cultivars or breeding lines were sap-inoculated and maintained in the screen house. Twenty-four of 29 legumes tested and 8 of 20 non-legumes tested developed viral symptoms or were shown to be infected by return inoculations on *Chenopodium amaranticolor*, a local-lesion host. The virus was transmitted in a non-persistent manner by the aphid *Aphis craccivora*. In Protein-A sandwich enzyme-linked immunosorbent assay (P-AS ELISA), sap from virus-infected plants reacted positively with antisera for two strains of blackeye cowpea mosaic virus (B1CMV). Symptomatology, host range, aphid transmission and serology putatively identify the virus as a strain of B1CMV. Bean common mosaic virus was not detected.

Yard-long beans are a variety of cowpea, *Vigna unguiculata* (L.) Walp. subsp. *sesquipedalis* (L.) Verdc., with an edible pod. On Guam, they are preferred to *Phaseolus vulgaris* L. varieties of green beans and are widely grown. An unidentified virus disease characterized by mosaic, dark-green vein banding and downward rolling of leaves infects plants on a number of farms. This virus has been shown to limit yield in preliminary field experiments. Control would remove one of the production constraints for beans on Guam. This study was initiated in order to isolate, characterize and identify the virus.

Materials and Methods

Mechanical transmission. Leaves of yard-long beans exhibiting disease symptoms were collected from the farm of E. Manibusan in Latte Heights, Mangilao, Guam, and used to inoculate 7-day old seedlings of *V. unguiculata* subsp. *sesquipedalis* 'local green'. Leaves were ground in a mortar with phosphate buffer, pH 7.9 (5 ml/1 g tissue). Test plants were dusted with carborundum (320 grit) and inoculated by gentle rubbing with a gauze pad saturated with macerate. Inoculated plants were grown in the screen house under diffused or artificial lighting.

Viral isolation. Sap from inoculated plants developing systemic symptoms was used to inoculate *Chenopodium amaranticolor* Coste & Reyn., in which three successive single local-lesion transfers were made. Then a single local lesion from *C. amaranticolor* was used to inoculate 'Yardlong Asparagus Bean' (W. Atlee Burpee & Co., Warminster, PA 18974). The virus isolate was propagated and maintained in this cultivar and in *Nicotiana benthamiana* Domin.

Host range. Three to eight test plants of 49 plant species, cultivars or varieties were sap-inoculated as described above, using young systemically-infected leaves of yard-long beans. Plants were maintained in the screen house. All inoculations were repeated. After 30 days, test plants were checked for presence of the virus by back-inoculations on *C. amaranticolor*.

Aphid transmission. Apterous *Aphis craccivora* Koch. from virus-free cultures were starved for 1 hr then given acquisition access to symptomatic yard-long beans for 30 sec to 2 min. Five aphids per plant were then transferred to healthy 7-day old yard-long bean seedlings for an inoculation feeding period of 4-6 hrs.

[1]Dept. of Ent. and Pl. Pathology, University of Tennessee, Knoxville, TN 37901-1071.

Serology. Assays were by Protein-A sandwich enzyme-linked immunosorbent assay (P-AS ELISA) as described by McLaughlin and Barnett (1978). Fresh leaf samples were ground in PBS-Tween (5 ml/1 g tissue). Antisera and antigen samples for the NL5 strain of BCMV and strain W of B1CMV were obtained from Dr. L. Bos of the Research Institute for Plant Protection, Wageningen, the Netherlands, and antiserum for B1CMV was obtained from Dr. C. W. Kuhn of the University of Georgia, Athens.

Results

Mechanical transmission and symptomatology. Yard-long asparagus bean plants (Burpee variety) inoculated with sap from diseased plants developed symptoms resembling those in farmers' fields. Mosaic, dark-green vein-banding, irregular blistering and twisting of leaves and downward rolling of leaves occurred in over 75% of mechanically-inoculated plants in the screen house. Some varieties of yard-long beans exhibited yellow flecking, yellow mottle, dwarfing of young leaves and distortion.

Host range. Twenty-four of 29 legume species, cultivars or varieties developed symptoms or were shown to be infected by back-inoculations on *C. amaranticolor*. All cultivars of yard-long beans inoculated developed systemic symptoms. Eight of 20 non-legumes tested developed symptoms or were shown to be infected by back-inoculations on *C. amaranticolor* (Table 1).

Aphid transmission. The virus was transmitted by the aphid *A. craccivora*. Over 60% of yard-long bean plants used in aphid transmission tests developed characteristic virus symtoms after 7-14 days at all tested acquisition times.

Serology. In P-AS ELISA antisera for both strains of B1CMV reacted positively with the sap from mechanically-inoculated yard-long bean plants. No reaction to healthy yard-long bean sap occurred. Sap from inoculated *N. benthamiana* plants also reacted positively to these strains.

Discussion

Symptomatology, host range, aphid transmission and serology putatively identify the virus as a strain of B1CMV. Planned development of an antiserum for this virus will provide the ability to rapidly screen yard-long bean plants for virus on Guam.

An investigation is currently underway to determine if the virus is seed-transmitted. Since most farmers on Guam save their seed for replanting, seed-transmission may be a major factor in spread of the virus. Host-range tests to identify local weeds which are reservoirs for the virus are also being conducted.

References cited

McLaughlin, M. R., and O.W. Barnett. 1978. Enzyme-linked immunosorbent assay (ELISA) for detection and identification of forage legume viruses. Pp. 138-145 *In:* Proc. 35th Southern Pasture and Forage Crop Improvement Conf., June 13-14, Sarasota, FL.

Table 1. Host range of a virus isolate causing aphid-borne mosaic in yard-long bean, *Vigna unguiculata* subsp. *sesquipedalis*.

FABACEAE—cowpea, fenugreek, sunnhemp, yard-long, soy, mung, bush, and fava beans

CHENOPODIACEAE— spinach, *Chenopodium amaranticolor* and *C. quinoa*.

AMARANTHACEAE—globe amaranth

SOLANACEAE—*Nicotiana benthamiana, Petunia hybrida.*

AIZOACEAE—New Zealand spinach

SWEET POTATO PRODUCTION TECHNIQUES IN MOLOKAI, HAWAII

GLENN I. TEVES

Cooperative Extension Service
College of Tropical Agriculture and Human Resources
P.O. Box 317, Hoolehua, Molokai, HI 96729

ABSTRACT Sweet potato farmers on Molokai have adapted farm implements from other crops to increase efficiency of production. These techniques could be adapted to other areas of the tropics.
New improved varieties developed by the University of Hawaii have increased yields and profitability, as well as variety. The flesh colors include white, yellow, orange and purple. Field trials in farmer's fields and at the Molokai Research / Demonstration Farm have produced yields upwards of 70,000 kg/ha. Increased consumer demand coupled with its nutritional importance in curbing Vitamin A deficiency can be important considerations in production of sweet potatoes in many areas of the Pacific.

There are very few places in the world where sweet potato achieved such historical and cultural prominence as in Hawaii, where it can be found in ancient legends. In places where taro was not adapted due to arid conditions or where rainfall was concentrated during one season of the year, sweetpotato was the staple of the inhabitants. The ancient Hawaiian could identify well over 225 varieties of sweetpotato.

Today, sweetpotato is making a comeback in the continental U.S. and also in parts of the Pacific. It is considered number three in nutritional value of all vegetables, being very high in pro-vitamin A. Some varieties have higher Vitamin C than tomatoes, especially orange and dark colored varieties.

Hawaii farmers produce over 560,000 kg. annually, with over 80% of the production grown on Molokai. Fifth in size of the Hawaiian Islands, Molokai is twice the land area of Guam, but with only 7,000 inhabitants. The ethnic make-up is predominantly native and part-Hawaiian.

Four native Hawaiian families produce about 73 ha. of sweetpotato, planting and harvesting weekly throughout the year. Average yields range from 15,000-20,000 kg/ha. Production techniques have steadily improved through the adoption of the following labor-saving machinery utilized for other crops.

A tobacco transplanter plants cuttings approximately 30-45 cm. long. Two individuals feed the cuttings into the transplanter while one individual follows behind to fill in the missing cuttings. Cuttings are planted 20-25 cm. apart in line on flat ground and 100-120 cm. between rows. These cuttings usually come from mature fields.

Weed control practices differ from farm to farm, with some farmers utilizing pre-emergent herbicide such as Amiben for weed control during the first month of growth. Other farmers employ cultivation techniques exclusively to control weeds at vital stages of growth, cultivating and side-dressing fertilizer in one pass, two weeks after planting.

Before hilling, which usually occurs 4-6 weeks after planting, plants are sometimes sprayed for sweetpotato weevil control with Sevin, especially in hot weather when infestations are bad. Farmers usually monitor the field to determine the level of infestation before determining whether to spray or not. Plants are then fertilized, hilled and cultivated in one pass. Two tubes place fertilizer 10 cm. to each side of the plant, plants are hilled with two large discs, and cultivator blades eliminate weeds between the rows. Size of the plant is the main consideration in determining when to hill, due to daylength and temperature differences between summer and winter. If hilled too early, plants can be covered over. Hilled too late, plants will sprawl and running over vines with the tractor will severely affect yield. Some varieties appear to be more affected than others.

Varieties take anywhere from 90-165 days to mature. When ready for harvest, the tops are mowed while one person follows-up with a sickle to detach any stems protruding from tubers. This is done so the sweetpotato does not get caught in the digging equipment. A sugar beet digger, adapted for use on other root crops, is utilized to dig sweetpotatoes out of the ground. The digger employs a V-shaped knife pulled under the crop row while a conveyor composed of metal bars lifts tubers out of the ground and drops them.

Soft-skinned varieties and immature tubers are easily damaged by digging equipment and soil moisture is very important in harvesting. In consistently moist fields, the skin does not have a chance to harden or suberize properly. Mechanical damage, followed by secondary fungal infections usually result. In very dry fields, dirt can scarify the surface of tubers.

Growers field grade tubers immediately after digging, and separate saleable from un-saleable tubers. Trailers are used to transport the saleable crop to the washing and packing shed for washing, grading, and packing. Grades include #1, #2, and jumbo, although some farmers will pack smaller tubers for specialty markets. Tuber are packed in 18 kg to 27 kg boxes, although wholesalers prefer the smaller boxes for handling ease.

The main variety for the last twenty five years has been Waimanalo Red. Of Okinawan origin, this red-skinned, beige-fleshed variety is earliest of all varieties grown in Hawaii. This variety is also the basis of the University of Hawaii breeding program headed by Jack Tanaka, who recently retired. Unfortunately, there are problems with Waimanalo Red. During winter months, this variety can be late maturing and low yielding. County agents on Molokai have initiated a screening program for the last 5 years to identify selections which are superior in yield to Waimanalo Red during winter months. The second step has been to screen these new selections at other times of the year.

Sweetpotato yields can range from 2.4 kg/m^2 to 9.6 kg/m^2 or 20,000 to 80,000 kg/ha. There are also other considerations, such as flesh color, skin color, tuber shape, taste, firmness, uniformity of shape, earliness, and disease resistance. The firm, dry-type sweetpotato is preferred by the local population over the moist-type sweetpotato preferred in the mainland U.S. The dry-type sweetpotato has greater tolerance to the sweetpotato weevil, compared to the moist type varieties such as Centennial and Jewel.

Along with Waimanalo Red, the main varieties on Molokai include:

1) Mokuau Red-Purple: seedling discovered by Molokai farmer, Hiene Mokuau. Red skin, deep purple flesh, dry-type, uniform shape,

2) Hoolehua Gold: cross between Centennial and Waimanalo Red. Red skin, orange flesh, very high yielding.

Other promising selections presently being evaluated include 71-5, 83-5, Ueunten, and Yoshida.

Weeds can be a serious problem that can adversely affect yields. One of the main weeds is Golden crown beard, *Verbesina encellioides*. Weedy relatives of sweetpotato, including hairy morning glory *Merrimea egyptica*, can harbor the sweetpotato weevil during periods when the crop is not present in the field.

The main insect pests of sweetpotato include the Sweetpotato Weevil, *Cylas formicarius elegantulus* (Summers) Curculionidae, Coleoptera; the Sweetpotato vine borer *Omphisa anastomasalis* (Guenee) Pyralidae, Lepidoptera; and the Sweetpotato Leafminer *Bedelia orchilella* (Walsingham) Lionetiidae, Lepidoptera. Of these, the Sweetpotato Weevil is the most destructive, and damage is more prevalent during hot, summer months. Keeping fields slightly moist will lessen weevil infestations by sealing the soil and creating a mechanical barrier. When the soil is very dry, it has a tendency to crack and afford the weevil easy access to the tuber.

Sweet potato collections are maintained at the Waimanalo Experiment Station on Oahu as well as at the Molokai Research-Demonstration Farm. Field days are held to expose farmers to new selections. Farmers also assist by personally evaluating varieties through taste tests and field observation. Cuttings of promising selections are made available to farmers for increase in their fields.

TARO [*COLOCASIA ESCULENTA* (L) SCHOTT] AGRICULTURE ON POHNPEI ISLAND, F.S.M.: PEST AND DISEASE OCCURRENCE AND CONTROL

BILL RAYNOR

Agricultural Experiment Station, College of Micronesia Land Grant Program, P.O. Box 1179, Kolonia, Pohnpei, F.S.M. 96941

ABSTRACT An RRA (Rapid Rural Assessment) survey was held on Pohnpei as part of the USDA/LISA Taro project. Nineteen farms were visited by the multi-disciplinary survey team. *Phytophthora* Leaf Blight was the major disease and overall major constraint in taro production on Pohnpei. Taro planthopper was the major insect pest, along with aphids, though most of the insect pests were at least under partial biological control. Perennial grasses *Paspalum conjugatum* and *Ischaemum* sp. were the major weed problem, though *Commelina*, *Chromolaena*, *Mimosa pudica*, and *Wedelia trilobata* were also serious pests on some farms. Farmers successfully controlled diseases, insects, and weeds by employing a number of cultural methods, both traditional and introduced.

As part of the USDA/ADAP-sponsored LISA Project entitled "A Comparative Study of Low and High Input Taro Systems in the American Pacific", a Rapid Rural Assessment (RRA) was held on Pohnpei island from January 22-26, 1990. The major goal was to document traditional management techniques in taro (*Colocasia esculenta* (L) Schott) production especially concerning the control of pests and diseases, maintenance of soil fertility, and soil conservation. This paper summarizes the findings of the RRA regarding pest and disease problems and control.

Farm visits were carried out in the five municipalities of Pohnpei Island: Sokehs, U, Madolenihmw, Kitti, and Nett. The multi-disciplinary RRA group was split into three survey teams to reach more taro growers, improve group interaction, and avoid overwhelming participating growers. Out of 24 growers selected in a pre-survey in December, the team visited 19 during the 5 day RRA (see Appendix 1.) Local extension staff selected growers who were representative of the main types of taro production; subsistence, semi-commercial, and commercial.

Overview of Taro Production

Colocasia taro is an important crop on Pohnpei, although it ranks behind rice, breadfruit, and yam as a staple food. Taro is especially important as a food at feasts and other cultural and religious activities. Generally, taro is grown by women, and growing it marks a woman as a hard worker and good provider. Characteristically, taro is farmed intensively in small patches near the residence. Further from the house, taro is grown in small clearings or under light shade in agroforest. Taro can be planted in monoculture or mixed with other crops, including breadfruit, banana, papaya, ylang-ylang, pineapple, sugarcane, yam, black pepper, and coconut. In monocropping, taro is often rotated with sweet potato, cassava, *Xanthosoma* taro, and vegetables (chinese cabbage, beans, cucumber, etc.)

Field Preparation and Planting. Land clearing was usually done by hand and with knives, although fields were sometimes burned. Growers near Kolonia often hired State Agriculture Division equipment to plow and bed fields. Planting material was mainly corm suckers 'ili ' with leaves removed, although a few farmers used corm tops 'paki'. To plant, growers made a hole in the cleared area using a digging stick or heavy metal bar 'ahk', or occasionally a machete or shovel. Growers who use tractor tillage prepared holes in the same way as traditional growers. Suckers were planted in a 8-15 cm depression in the hole. Fertilizer was sometimes applied at planting. Plant spacing varied from 0.6 m X 0.6 m to 1 m X 1.3 m feet. Planting dates varied amongst growers, and most growers felt that taro could be successfully planted all year. Commercial growers pointed out that market demand is highest in November-December, and they planted accordingly.

Care and Maintenance. After planting, weeding was the main cultural practice. All growers practiced hand-weeding, although a few also used hoes. Mulching was not used much, perhaps due to a lack of labor (most women worked the taro farm by themselves) or to high rainfall which caused plants used as mulch to resprout.

Imported commercial fertilizer was sometimes used, the most common system of fertilization being two 28 g applications of 10-20-20, one at two to three-leaf stage, and another after 2-3 months. Chicken manure and goat manure was used on occasion if available.

Hilling was practiced by most growers after the corm grew above the soil level (about 3 months after planting). Suckers were generally removed and used to plant new areas. After harvest some growers left late season suckers to act as a "ratoon" crop.

Harvest and Marketing. Women, sometimes with the help of other family members, harvested the taro after 4-8 months, depending on site and cultivar. The taro was harvested when the leaves began to got smaller and fewer, and roots were weak, making the corms easy to pull. Growers reported yields of up to 4.5 kg per corm, though 0.5-1.5 kg was more common.

Soil Conservation. Growers practiced several methods of soil conservation on their farms. Mulching, minimum cultivation (working soil only at planting hole), using pieces of wood arranged around the taro to hold up the hilled-up mounds, leaving trees felled in clearing around the borders of the field, and agroforestry characterized non-mechanized farms. On tractor-cultivated farms, growers used terracing, drainage and diversion ditches, and contour beds.

Cultivars. Over 10 cultivars of *Colocasia* taro were grown on Pohnpei (see Appendix 2.) *Sawa toantoal* was the most popular taro because of it's excellent taste and eating quality, but it yielded only moderately. The second-most common cultivar is *sawahn Kosrae*, which is well-liked and was reported to be more resistant to pests and diseases than other cultivars. *Pasdora*, a cultivar known for high yields, was third. Most growers planted more than one cultivar, expressing the traditional Pohnpei practice of mixing numerous cultivars in plantings.

Diseases and Pests and Their Control

Diseases. *Phytophthora* Leaf Blight, caused by the fungus *Phytophthora colocasiae* Rac., was the most important pest of taro and was cited by most growers as their major production problem. It was reported to wipe out entire fields during certain periods of the year. *Phytophthora* was observed on all farms, although infection levels were not serious during the week of the RRA. The most common control methods were cutting off the diseased leaves and removing them from the field. A few growers burned the leaves after removal. This cultural method has been reported from other areas, and is reported to be successful in decreasing leaf infection during the first 2-3 months of crop growth (Jackson 1980, Ooka & Trujillo 1982). One grower reported that removing all the leaves during a severe infection was a possible method to avoid losing an entire field. Some growers suggested that planting time might affect *Phytophthora* outbreaks and severity but there was little agreement on a best planting time. January-March (the "dry" season) was suggested as the best planting time by a few growers, while another reported that taro planted in June had a lot less *Phytophthora* Leaf Blight than taro planted in November. Some growers also suggested that one cultivar, *Sawahn Kosrae*, was somewhat resistant to *Phytophthora* and other diseases and pests, although this has not been borne out by past research (Dayrit and Phillip 1987.)

Dasheen Mosaic Virus was also widespread, though not recognized as a problem by any of the growers. Shothole (caused by *Phyllostica* sp. fungus) was identified on 6 farms, and corm rot (possible *Pythium* sp.) was reported on 4 farms. Corm rot was mainly a problem in overmature taro. Southern Blight fungus (*Sclerotium rolfsii*) was found on three farms, mainly in connection with high organic matter and high temperatures.

Insects. Taro planthopper (*Tarophagus proserpina* Kirk. (Delphacidae)) was the major insect pest observed on the farms. All farms either had planthopper in evidence or reported by growers, who mentioned periodic serious outbreaks of the pest. Damage from the planthoppers was recognized by growers, although in some cases, descriptions sounded more like the symptoms of *Phytophthora* Leaf Blight. Planthoppers were under biological control in at least 5 sites, most commonly by the egg predator *Cyrtorrhinus fulvus* (Miridae), which was introduced to Pohnpei in 1947 and again in 1955 (Esguerra 1988). Immature *C. fulvus* specimens were observed (orange-colored, compared with black and yellow when adult). Webs, probably pupation sites of a wasp parasite (family Dryinidae) that attacks planthopper nymphs, were observed on some leaves. Leaf removal was the only common cultural practice used for pest control, although two growers reported using

Malathion on an irregular basis to control planthoppers and aphids.

Aphids were the second most common insect, and were observed on 17 farms (90%). All aphids observed, which were quite variable in appearance, were probably the melon aphid (*Aphis gossypii* Glover.) The only predators observed were syrphid larvae. Aphids were numerous in some plantings, but damage seemed to be minimal. Growers reported removing and burning infested leaves during severe oubreaks.

Armyworm or Cluster Caterpillar (*Spodoptera litura* (F.) (Noctuidae)) was present, and worms or egg masses were observed on six farms. At least some of the egg masses were parasitized by a wasp tentatively identified to be member of the family Scelionidae (Schreiner, personal communication). Growers controlled armyworms by hand-squashing both worms and egg clusters on a regular basis.

Taro Hornworm was not observed during the survey and has probably not yet reached Pohnpei. Mealybugs were observed at one farm, and grasshoppers were mentioned by one grower as an insect pest.

Weeds. *Paspalum conjugatum*, a common grass, was the major weed pest (11 farms), with *Ischaemum* sp. second (5 farms). *Commelina diffusa, Chromolaena, Ageratum, Mimosa pudica, M. invisa,* and *Wedelia trilobata* were also reported as major weeds on a few farms. Numerous other weed species were observed and identified (Appendix 3). In general, weeds were well controlled on nearly all farms, mainly by hand-weeding. Herbicides were not commercially available to farmers.

Besides hand-weeding, a traditional method of weed control was to pick a new, fertile site and plant cultivars that got ahead of the weeds in the early growth stages. Taro was weeded when it was clear that it had successfully established (i.e.beat the weeds). The benefits of rotating taro onto new sites, in terms of soil fertility and lower weed pressure, is well-known (i.e. Plucknett, 1982). Generally, weeds are removed from the field, though some growers used pulled weeds for mulch, and two reported that they worked the weeds into the new planting beds as fertilizer.

Other Pests. Pigs were reported to be a problem on three farms, mainly in Kitti municipality where the local ordinance requiring fencing of pigs is not strictly enforced. Fencing with rocks, sticks, or other material is commonly used to minimize pig damage, although this was generally not practiced on the farms visited.

Future Research Areas

As part of the RRA, the multi-disciplinary team identified possible research projects for the LISA project to address. *Phytophthora* Leaf Blight was felt by the RRA participants to be the major priority for future research. After numerous discussions with local farmers, strategies such as planting time, cultivar resistance, plant density, shade/mulching, leaf removal, and improved soil fertility were identified as traditional disease control techniques. These could be investigated in a single or series of experiments to determine how effective each strategy is. A research proposal on planting time and taro yield and incidence of *Phytophthora* Leaf Blight has been submitted to the LISA project by COM researcher Ben Dayrit and this author for consideration.

The group also felt that a long-term study of pest and disease pressure would be valuable, especially in helping determine factors leading to severe infections and infestations. A possibility would be to monitor 10 farms on a two-week pest and disease sampling schedule for the period of a year or more. Other data, such as weed incidence and crop rotation, could be monitored at the same time.

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Appendix 1. Pohnpei Island farmers surveyed in the RRA.

Name of farmer	Location of farm	Age of farmer	Number of plants	Type of farm
Lwiter Iouanis	Paies, Sokehs	50	300	Subsistence
Erlina Iouanis	Paies,-Sokehs	30	400	Semi-commercial
Metrihna Jacop	Paies, Sokehs	39	200	Subsistence
Ruth Luis	Kepra, Sokehs	39	150	Subsistence
Suanihda Jona	Kepra, Sokehs	50	120	Subsistence
Primo Jack	Kepra, Sokehs	31	50	Subsistence
Klarise Inoke	Nanwelin U, U	36	50	Subsistence
Francisco Hedgar	Saladak, U	38	30	Subsistence
Asuncion Panuelo	Dien, U	41	30	Subsistence
Roberta Ladore	Awak, U	55	20	Subsistence
Markarida Lipai	Dolonier, Nett	40	200	Subsistence
Mauro Moses	Meitik, Nett	45	200	Subsistence
PATS High School	Lepwultik, Nett	—	2 acres	Commercial
Biretelain Emilos	Kinakapw, Nett	52	50	Subsistence
Elsina Johnny	Lukop, Nett	51	50	Subsistence
Sale Martin	Paies, Kitti	60	200	Commercial
Anna Barnabas	Tomwoaroalong, Kitti	30	150	Subsistence
Rosanda Rosario	Wene, Kitti	27	200	Subsistence
Eltrina Hadley	Wene, Kitti	50	200	Subsistence

Appendix 2. Major *Colocasia* Taro Cultivars on Pohnpei Island.

Sawa likodopw- ("Freshwater prawn taro")- This is probably an old introduction (possibly pre-European contact). It is not eaten anymore, although it may be fed to pigs. It grows wild in wet areas.

Sawa pwetepwet- ("White taro")- One of the popular cultivars, this dryland variety makes many suckers and often becomes weedy after harvest. Production is good and corm is pinkish-white and rather soft.

Sawa toantoal- ("Black taro")- Probably the most popular dryland variety, mainly because of taste. Corm is purplish-white and hard. This cultivar is believed to be the same as the Guam cultivar 'bisaya'.

Pasdora- This dryland taro was brought from Palau in the 1950's by a local farmer, Gregorio Ladore who named it after his wife. It is very popular, and seems to be the highest yielder.

Kuat- Reportedly very popular during the Japanese mandate (1918-1945), now not well known. Prefers swamp cultivation, and seems to yield well in this situation. Corm has yellow flesh and a nice smell when cooked.

Sawahn Kusaie/Kosrae- ("Kosraen taro")- Name suggests introduction from Kosrae. Fairly popular with strong growth under dryland conditions. This taro flowers when it reaches maturity.

Sawahn alahl- ("Variegated color taro")- Probably a fairly recent introduction from Hawaii or Guam. Two types are on Pohnpei, red and green. It does not yield well, and is grown mainly for its novelty.

Sawa mwahng- ("Cyrtosperma-like taro")- Probably a fairly recent introduction. Not common but highly valued. Color of flesh is like *Cyrtosperma* and suckers set very close to the main corm, thus the name.

Appendix 3. Major weed species in taro fields in Pohnpei Island.

Most important species roughly in order of importance:

1. *Paspalum conjugatum*
2. *Ischaemum* sp.
3. *Mimosa invisa*
4. *Commelina diffusa*
5. *Chromolaena odorata*
6. *Mimosa pudica*
7. *Wedelia trilobata*
8. *Ageratum conyzoides*
9. *Euphorbia hirta*

Other weeds noted in the survey:

Amaranthus sp.
Oxalis sp.
Zingiber sp.
Melastoma marianum
Ipomoea spp.
Phyllanthus niruri
Polygala paniculata
Hyptis sp.
Dalbergia candenatensis
Centella asiatica
Vernonia cinerea
Emilia sp.
sedges
other grasses
ferns

TRADITIONAL CROP PROTECTION IN OCEANIA: A PRELIMINARY REVIEW

HARLEY I. MANNER

College of Arts and Sciences, University of Guam
Mangilao, Guam 96923

ABSTRACT In view of the increasing interest in agricultural sustainability, the traditional agricultural systems of Oceania offer the world a range of sustainable crop protection methods. This paper reviews the literature and incorporates observations of traditional systems spanning 23 years. Crop protection refers to the range of activities and methods used by traditional agriculturalists to impart a real or perceived protection to the garden, farm or crop components of these systems which may have a crop protection component include spacing of gardens, shifting cultivation, fallows, polycultures and varietal diversity. Mounding, mulching and control of water flow may also have crop protection usages. The efficacy of these systems and methods of crop protection must be viewed within their socio-economic-environmental contexts, and should be experimentally studied. These traditional methods may offer modern agriculture more sustainable and less expensive methods of crop protection.

With the increasing interest in agricultural sustainability and farming systems, recent research has started to focus on traditional (indigenous) agricultural systems because of their use of a range of sustainable methods and the perception that many of these methods are protective of the environments in which they are practiced. Many traditional systems of agriculture in Oceania are considered to be sustainable within their socio-economic-environmental contexts, because of their characteristics of independence, self-sufficiency, reliance on human energy and ecological processes rather than fossil fuels (Clarke 1977).

This presentation is a review of the crop protection methods used by traditional agriculturalists in the Pacific islands. As will be shown, there is relatively little written information on the traditional methods of crop protection in the Pacific islands. However, crop protection is an integral part of traditional agricultural systems, and achieved through the use of multipurpose practices (those not specifically classified as crop protection), and those which are specifically classified as crop protection. Reasons for the relative lack of information on crop protection in traditional agricultural systems will be examined briefly.

Two other points need to be emphasized. First, the objectives and values of traditional agriculturalists are quite different from commercial agriculture. While high productivity is a goal of commercial agriculture, the goals and objectives of traditional agriculture are often quite different. For example, a common practice of many traditional agricultural systems is polyculture, which while providing the subsistence agriculturalist with a wide range of different crops, may reduce overall productivity, although this has not been adequately tested. Other examples include the production of subsistence and culturally valued foodstuffs which may not have significant economic value, or may be less productive than other foods; the practice of long fallows and less intensive methods of cultivation, to name a few. While productivity in these systems may be low in terms of time and area, such methods are perceived to be environmentally conservative.

Thus in many traditional systems, high productivity may not be the main objective. Agriculture provides other functions. Agriculture is a social/cultural process of which food production is but one aspect. The garden and its products fulfill other obligations and responsibilities, which may be more important than production. In many parts of the Pacific, agriculture fulfills one's social and ritual obligations. For example, yams (*Dioscorea* spp.) have ritual and prestige significance in Pohnpei (Bascom 1948; Raynor 1989), and as such, are not determined by market functions. Agriculture in the Pacific is integral to land tenure and a person's social position; it is a way by which cultivators reaffirm their stewardship of and rights to land. If the lands are not cultivated, the rights may be presented to someone else. Second, many traditional agricultural systems reflect a long standing adaption to a particular cultural-environmental context. The introduction of more intensive methods of agriculture has seriously disrupted agricultural production, environment, and socio-cultural dynamics in many parts of the Pacific.

Crop Protection: A Broad Definition. While this conference is primarily concerned with protection from viral, fungal, bacterial and insect pests, a broader view is taken here. In this paper, crop protection refers to the range of activities and methods used by traditional agriculturalists to impart a real or perceived protection to the garden, farm or crop. In this connection, traditional protection methods may not be completely effective, nor is it solely the realm of concern of entomologists and crop protection specialists.

This paper considers a) shifting cultivation, the traditional system of agriculture and its crop protection attributes; b) Specific methods of traditional crop protection; and c) the reasons for the lack of information on traditional crop protection. These methods are summarized in Table 1.

Crop protection in a traditional agricultural system: shifting cultivation. Particularly in Melanesia and some parts of Polynesia and Micronesia, shifting cultivation or slash and burn agriculture is a common form of traditional agriculture practiced in both primary and secondary forest fallows. In this system, of which there are many variants, selected areas of forest are slashed with simple tools, the litter burned when it is sufficiently dried, the area planted with a variety of crops (polyculture), and abandoned to fallow after a few years of cultivation. Under conditions of low population density, fallowing results in the regeneration of forest and its ecological benefits (for example, the regeneration of soil fertility). Given these practices, crop protection is an integral aspect of this system.

The benefits of burning as a method of litter reduction, soil fertilization, and pH amelioration have been cited often (Manner, 1981; Clarke, 1977; Siwatibau, 1984). Such burning also kills weed propagules and potential insect and fungal pests, although the efficacy of burning vis a vis crop protection, has not been well established. What effects burning of the litter and the resultant changes in soil pH, temperature and moisture have on the fungal, viral, and bacterial problems of traditional agricultural systems are not known or rarely have been studied.

Polyculture and ecological succession in gardens. In these land extensive systems of traditional slash and burn agriculture, gardens are planted with a diversity of species (polyculture) which supposedly reflects the structural and functional dynamics of ecological succession in a tropical rainforest ecosystem. For example, the gardens of the Kompiai Mareng of Papaua New Guinea contain between 3.5 and 10 species of cultivated plants per 25 m^2 (Manner, 1981), the composition of which changes with time. Newly created gardens contain a higher number of cultivated species and are dominated with *Colocasia esculenta, Dioscorea* sp., and other rapidly maturing vegetables, while older gardens contain fewer species and are dominated by sweet potatoes (*Ipomoea batatas*), *Saccharum edule*, *Saccharum officinarum*, and bananas (*Musa* sp.), species which may be better adapted to decreased soil fertility and increased weediness. While this human-directed sequence of phased cultivation and harvest corresponds with the rates of cultivar growth and maturation, it may also reflect the concentrations and effects of host specific pests. Crop succession (or rotation) may be viewed as a method of maintaining high site productivity despite specific pest infestations. Yen (1974:44) states that the "change of species allays the progress of further buildup of pathogens affecting the first (crop), and at the same time endows a relatively disease-free period for the second", and as species vary in their tolerances to environmental limitations, polyculture is an effective way to insure some production in case of injurious frost, drought, or other factor.

Varietal diversity. High varietal diversity, another characteristic of traditional extensive agriculture, may be considered a crop protection method. Many gardens contain more than one variety of a particular food plant species. The newly created gardens of the Kompiai Marengs contain 24 varieties of cultivated food plants per 25 m^2, a figure which decreases to 6.5 varieties per 25 m^2 at the end of three years (Manner, 1981). I suggest that cultivar and varietal diversity, while presenting both physical and/or chemical barriers to pests, and is a form of environmental "insurance" as the resultant density of a particular food plant (cultivar or variety) may be less than the threshold levels necessary for attracting and maintaining a pest population. "Insurance" is further enhanced as varieties differ in their resistance to diseases, moisture stress and other environmental variables.

Varietal diversity is also high on atolls despite the harshness of the atoll environment. Manner and Mallon (1989) listed the following species and the number of varieties present on Puluwat Atoll: *Artocarpus altilis* (29), *Artocarpus mariannensis* (7), *Cocos nucifera* (9), *Colocasia esculenta* (29), *Cyrtosperma chamissonis* (24), and *Musa* x *sapentium* (23). By way of contrast only two varieties of *Colocasia esculenta* are noted for Ulithi Atolls (Lessa 1977). The numbers of *Pandanus tectorius* and *Cyrtosperma chamissionis* varieties in other atolls of the Pacific are also quite high (Ali and Asghar 1987).

Fallowing as a method of crop protection. After one or more years of cultivation, gardens are abandoned to fallow, with the lengths of cultivation and fallowing depending upon both environmental and cultural factors. Under conditions of high population density, the length of cultivation may exceed the length of fallow, whereas the opposite may hold under situations of low population density. Among the Marengs of the Bismarck Mountains of Papua New Guinea, gardens are abandoned after 1 - 1.5 years of cultivation. Fallow periods of 15 years or more, which result in the succession to mixed forest, are not uncommon. By way of contrast, in the more densely populated territories of the Enga and Chimbu, garden plots may be cultivated for periods up to 5 years. The fallow period is often reduced to 6 months. With shortened fallow lengths, the successional vegetation is dominated by grasses and shrubs.

There are many reasons for garden abandonment. Often cited reasons are the decline in soil fertility and productivity, which with fallowing results in the restoration of soil fertility by the successional vegetation through biogeochemical cycling. Less cited reasons include the high energetic costs associated with weeding and maintaining fences (Clarke 1977). Diseases and pest infestations are another, albeit unknown factor. With fallowing, the concentrations of various host-pest complexes are decreased with the return to forest or grassland. In American Samoa, fallowing of three months and not replanting in the same hole is used to control pest infestations (Vargo 1990).

Geographic spacing of gardens.

A common practice among slash and burn agriculturalists is to maintain more than one garden in different parts of his/her territory. At any given point in time, the cultivator will have more than one series of gardens in different stages of growth and maturation. The underlying rationale of this practice which may be summed up in the adage "Don't put your eggs in one basket," is to minimize the effects of crop failure or disaster by spreading the risk over geographic space. Thus if one garden is destroyed by physical or biological processes, or fails to produce as expected, the traditional agriculturalist has other gardens to rely on. A second advantage of this practice is that it uses of a range of environments, each with different carrying capacities and capabilities for the production of different food plants and varieties.

Permanent tree gardens of Micronesia.

Some of the above practices are also used in Micronesian agroforests of Yap, Pohnpei, Kosrae and Chuuk, which some authors (for example, Raynor 1989) claim are the most stabilized and complex form of tropical agricultural production. These agroforests, contain a wide variety of trees and herbaceous crops which provide the cultivator with a range of food, fuel, and other plant resources. Crop protection benefits of this system of land use probably include the following: decreased soil erosion and slumping; minimization of temperature extremes; "insurance" as described previously; fewer pests and diseases as a result of the spacings between plants and the wide variety of plants present; and lower threshold levels for particular pests, and therefore less damage. There is very little information on these impacts and interactions for the Pacific region.

Other methods of crop protection. This category includes the modifications of micro-topography or relief employed by traditional agriculturalists in order to protect a crop or garden from adverse environmental and other impacts.

Mounding. In Papua New Guinea, traditional agriculture is conducted on the high mountain slopes and valleys at elevations up to 2100m. Frost damage, associated with cold, descending air is an occasional problem at high elevations. The Enga and other high mountain or valley dwelling agriculturalists plant their crops on large oval (semi-elliptical) mounds (3m x 5m) which stand approximately 1 meter high (Waddell 1972). These mounds are planted with a variety of crop species with frost resistant species planted near the base of the mound, while frost sensitive species planted closer towards the top (and more protected section) of the mound. Because of its higher density, the cold air moves down slope as a ground-hugging layer and flows around the mounds rather than over it.

At lower elevations where frost is not a problem, and on valley bottoms subject to waterlogging, mounds are created mainly for the purposes of increasing planting depth and soil aeration, and decreasing waterlogging and micronutrient toxicities associated with anaerobic soil conditions (Clarke and Street 1967). Where population densities are high, mounds are built in grasslands to offset clayey, compact and anaerobic soils which inhibit good rooting structure. Green manures are also added to increase soil fertility and tilth. Ditches which remove excess water and provide a barrier to access are often found in association with these mounds.

On Pacific island atolls, salt water intrusion of the freshwater lens and salt water inundation because of high tides or waves are problems of atoll food production. Mounds are also created in these environments for the production of food. These mounds are built in natural and excavated depressions, usually located towards the geographic and hydrologic center of the islet where salt spray and water damage is less, for the cultivation of staple and other food crops and ornamentals. On Puluwat Atoll, the "maa" (mounds) have an oval base and frame constructed with coconut and pandanus logs, which is then filled with organic matter to form an organic soil layer which stands about 1 meter above the water level (Manner and Mallon 1989).

Hydroponic tanks offer even better protection from salt water intrusion. Since the end of World War II, the people of Ulithi and other atolls in Yap State have successfully grown *Colocasia* and *Cyrtosperma* taro in abandoned landing barges and other large containers. The Ulithians also grow taro in concrete tanks, which measure 4 x 8 x 1 m (w x l x h). These tanks are filled with rotting organic matter which forms a floating organic mat.

Windbreaks. Particularly on windward coasts, windbreaks are used to break the strength of strong winds and salt spray. Evidence of salt spray can be found on many coastlines where the coastal vegetation has been salt-planed: the height of the canopy gradually increases with distance inland (Wiens 1963). On many atolls, the coastal fringe of natural vegetation is left undisturbed as it serves as a barrier to salt spray. Further protection to crop plants is achieved by locating salt sensitive food plants and gardens towards the hydrologic (and often geographic) center of the islet where salt spray damage and salt water intrusion of the freshwater lens is less.

Mulching. Mulching with organic materials (including weeds) ostensibly to conserve soil moisture and thus allay the effects of drought, and to suppress weed regrowth, is commonly practiced in many agricultural systems in the Pacific.

Artificial and natural shading is used to protect young plants from excessive sunlight and high temperatures. In Fiji, *Colocasia esculenta* is interplanted as a shade for young *Piper methysticum* (kava, sakau), and in the less traditional plantation economies of the Pacific, cocoa seedlings are usually protected from sunlight with shading woven from coconut fronds.

Traditional methods of pest control. Traditional biochemical control methods have rarely been reported. In American Samoa, *Coleus blumei* is planted in taro fields either as a planthopper deterrent or attractant, and plant hoppers are controlled by the heat of a flaming torch (Vargo, in press). In Rarotonga, Cook Islands, a fungal leaf disease of sweet potatoes caused by *Cercospora* is lessened by planting roots instead of vines (Yen, 1974:62). On Ulithi Atoll, *Phytophthora* leaf blight, dasheen mosaic virus, aphids, hornworm, and planthoppers are present but do not seem to be major problems (Manner 1991). As elsewhere in the Pacific, hornworms and army worms are controlled by hand removal.

In early Hawaii, taro corm rot, which was called 'pala' or 'palahe', was controlled by selecting healthy corms, fallowing the 'lois' for 2 to 3 months after drying, and maintaining a continuous flow of water through the 'loi' during cultivation (Handy 1940). Other procedures included draining and drying the 'lois', replanting with healthy cormels of a different variety and from a different locality (Handy 1940). Perhaps stemming from these and other traditional practices, the South Pacific Commission recommendations for the control of *Pythium* corm rot included deep cultivation of the field and exposure to the sun and dipping corms in a copper fungicide (O'Conner 1967).

Even though the rhinocerous beetle and the *Phytophthora* leaf blight have greatly disrupted the traditional agricultural systems of the Pacific, there is little information on traditional control methods for these problems.

Although specific information on traditional crop protection methods is rare, many present day practices of crop protection methods have their roots in traditional agriculture. For example, Thurston's (1984: 54) recommendations for the control of the Philippine downy mildew of maize, in the Philippines include eliminating weed hosts, manipulating planting dates to avoid the disease, regulating planting density, using wider spacing, or interplanting maize with other crops, and planting maize in a given area only once a year to name a few.

The lack of information on traditional methods of crop protection. The previous discussion has indicated that relatively little documentation about traditional crop protection methods is available. This section briefly examines some reasons for the apparent lack of documentation.

Among students of traditional agriculture in Oceania, crop protection methods and techniques have been least studied, perhaps as an oversight, but in addition, because of the complexity of the traditional agricultural system, as suggested by its polycultural diversity, and its integration with the dynamics of ecological succession, albeit modified by human action. Thus analysis of the structure and dynamics of a traditional polycultural system is an enormous task, one for which few agriculturalists have been trained to do and one which lacks clearly defined methods of analysis (Raynor 1989). And as traditional agriculture often lies in that "grey area" of academic study, most of the research on traditional agricultural systems, including agroforestry, has been accomplished by geographers and anthropologists, the majority of whom have little training in entomology or crop protection, or the understanding of the complexities of pest-host interactions.

Economic imperatives, initiated by former colonial enterprises and governments, fostered the plantation production of marketable and usually exotic crops at the expense of traditional food crops. During most of the agricultural history of the Pacific, there were few, large export markets for the principal island staples of taro, yams and breadfruit. Except for coconuts for copra and coconut oil, and sugarcane, which were a part of the subsistence economy, most export crops (coffee, cocoa, vanilla, pineapples, to name a few) were alien to the traditional agricultural systems of the Pacific and grown primarily on estates or plantations, rather than in the traditional subsistence garden. Not unlikely, monies for research were mainly limited to these export crops, aided and abetted by the colonial viewpoint that the traditional agricultural system was inferior to the plantation mode.

In addition, agriculturalists (including entomologists) have rarely studied the traditional agricultural systems of the Pacific. Thus, references to the crop protection methods used by traditional agriculturalists and in the Pacific Basin are few. The apparent lack of information on crop protection in Pacific traditional agriculture suggests three other hypotheses: that crop protection was not wholly necessary as crop pests were minimized by cultural practice; that there were few traditional pests; third, pest infestation and some crop loss was accepted as an inevitable consequence; and, fourth most pest problems are relatively recent occurrences and of alien origin. These hypotheses offer further avenues of research, and given the lack of information cited above, I can only suggest that a focused study of traditional crop protection methods can be of significant value to Pacific island agriculture.

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Table 1. Traditional Crop Protection Methods in Oceania

Factor	Method of control	Location and or protection and additional notes
Frost and low temperatures	Mounds and drainage channels	Papua New Guinea at elevations up to 7000.'
Drought and moisture stress	Mulching with weeds and other organic materials	Pacific-wide. Cardboard and Pandanus mats are used in Am. Samoa.
High temperatures & sunlight	Shading	In Fiji, young *Piper methysticum* (kava) are shaded from strong sunlight by interplanted taro.
Waterlogging	Mounds and drainage channels	Papua New Guinea. Valley and bottom lands.
Micronutrient toxicities of anerobic and waterlogged soils.	Mounds and drainage channels	Papua New Guinea. Valley and bottom land areas
Salt water intrusion	Hydroponic tanks	In Ulilthi Atoll, Yap State abandoned landing barges and other large containers are used to grow taro.
Weeds (seeds)	Burning	Pacific-wide, particularly in areas of extensive slash-and burn agriculture.
Weeds	Mulching with weeds, organic manures, or other materials	Pacific-wide, Guam.
Weeds	Fallowing or garden abandonment	Melanesia. As weeds become more of a problem with garden age, the cultivator will abandon the garden to fallow.
Insects, viral, bacterial, fungal diseases	Heat & burning of litter and cleared vegetation	Pacific-wide. An inferred control method, associated with changes in soil pH, particularly in areas of slash and burn agriculture.
Insects, viral, bacterial, fungal diseases	Fallowing or garden abandonment	Pacific-wide. A inferred control method, also used in modern agriculture.
Insects, viral, bacterial, fungal diseases	Polyculture	Pacific-wide. Through interplanting of many different species in he same plot tthe density of a particular food species is lowered, thus reducing the numbers of host specific species.

Table 1. Traditional Crop Protection Methods in Oceania (Continued)

Factor	Method of control	Location and or protection and additional notes
Insects, viral, bacterial, fungal diseases	Cultivar diversity	Pacific-wide. Cultivation of more than one cultivar of the same species in the same plot. As cultivars vary in their resistance to diseases, the maintenance of cultivar diversity reduces total crop loss.
Insects, viral, bacterial, fungal diseases	Crop rotation	Pacific-wide. An inferred control method, also used in modern agriculture.
General crop failure	Geographic isolation (Spatial segregation)	Pacific-wide. Cultivation of more than one garden at the same same time. If one garden fails, the cultivator is assured of a harvest from the other gardens.
Theft and animal damage	Fences, ditches & stone walls	Pacific wide.
Theft and animal damage	Magic, ritual plants	Pacific wide. Certain plants perceived as "magic" are planted for garden protection.
Insects	Hand picking and squashing	Pacific-wide practice, particularly noted for control of horn worms.
Insects	Shaking of leaf	Pacific-wide. With handshaking of leaf, insects fall to ground.
Insects	Scorching of leaf	Pacific-wide. Light scorching with a firebrand to kill insects.
Insects	Biochemical control	Pacific wide. In American Samoa, *Coleus blumei* is reputed to be effective against plant hoppers. InFiji, *Tagetes erecta* is planted as a border to reduce insect infestations

CORM ROTS OF TARO IN MICRONESIA

G.V.H. JACKSON

Plant Health Officer, South Pacific Commission
Private Bag, Suva, Fiji

ABSTRACT Root and corm rot diseases of giant swamp taro and *Colocasia* taro in Micronesia are described. The nematode, *Radopholus similis*, is commonly associated with a dry corm rot of giant swamp taro in Yap and to a lesser extent in Palau and Guam. *Pythium* fungi have been isolated from severe corm and root rots of wet land *Colocasia* taro in Palau. A possible association of these two diseases is being investigated.

The giant swamp taro, *Cyrtosperma chamissonis*, and taro, or sweet taro, *Colocasia esculenta*, are important traditional food plants of Micronesia and are still commonly cultivated. They are grown using a variety of cultural techniques in several different environments. In the swamps adjacent to the coastal mangroves on high islands they are grown together, but in many other situations they occur as monocrops. This is so where *Colocasia* taro are cultivated under rainfed conditions and particularly where sophisticated methods have been developed to intensify production of either crop. *Colocasia* taro is grown in complex irrigated gardens and *Cyrtosperma* in mulched pits, which in coraline islands and atolls, in particular, are dug to tap sources of fresh water - a technique which has led to the exploitation of an otherwise inhospitable environment.

The systems that have been developed are durable; they have been selected for their hardiness and dependability. For the subsistence grower, the long term security of the crop is most important and maximizing yields a secondary consideration. In these situations, therefore, it is generally supposed that pests are not important, or are controlled by cultural techniques. But this may not always be so. In addition to taro leaf blight fungus, *Phytophthora colocasiae*, which is a recent introduction to the region, serious corm rot diseases occur, which are probably traditional problems of both these crops.

Giant swamp taro, *Cyrtosperma chamissonis*

The disease. Corm rot has been recorded from Yap island and Ulithi atoll in Yap State of the Federated States of Micronesia, from Kayangel atoll and Babeldaop island in Palau and from Guam. The rot has long been present in Yap and Palau, but in recent years it seems to have increased in severity and is now of serious concern. Less is known about the disease in Guam. It has only been seen in one locality, a swamp used by people originally from Yap and Palau.

Above ground, plants look healthy; only the corms show symptoms. These appear to have been attacked by chewing insects. Shallow craters, 0.5-2 cm diam and 1-2 cm deep, cover the surface. Beneath these are dry brown rots, mostly 0.5-1 cm deep, but sometimes extending to the centre of the corm. Roots are not obviously damaged.

Because of these rots, a considerable amount of decayed tissue has to be pared away before corms are fit for human consumption. The amount of damage varies with locality, the age of the crop, and possibly differences in cultivation techniques. In Yap, for instance, damage is considered to be less in coraline soils close to the sea compared to that in heavier soils further inland. In taro patches, recently brought back into cultivation after lengthy fallows in Yap, the loss is about 10 to 15%. Where taro are grown in patches that have been in continuous production for generations, and this is the normal situation, losses are far greater, between 30 and 50%. Notwithstanding the difficulty of actually measuring the damage, the general opinion of growers in Yap, at least, is that the problem is getting worse. This is ascribed to a decline in the care of the taro patch: allowing too much shade from bordering trees; leaving fallen leaves to accumulate; failing to dig the patch; burying green leaves and allowing them to ferment before cultivation; failing to dig peripheral ditches and preventing soil falling into the patch.

The cause. Morwood (1958), in his report: "Diseases of Plants in the Trust Territory of the Pacific Islands" appears to have been the first person to document the problem. He considered that the fungus *Pythium* was the cause of "a firm rot of irregular areas around the surface (of the corms) which penetrates about one inch". Later, Trujillo (1971) "A List of Diseases of Economic Plants in the Trust Territory of the Pacific Islands" also gives *Pythium* as the cause of a dry rot of corms in Koror (Palau), Kayangel and Pohnpei. Curiously, there is no mention of the disease from Yap.

In 1984, corms with rot were sent to the Department of Scientific and Industrial Research, New Zealand, and the burrowing nematode, *Radopholus similis*, was extracted from the decayed tissues. Later, the identification was confirmed when samples were sent to the C.A.B. International Institute of Parasitology, U.K., to establish a culture for pathogenicity tests.

Spread of the disease. Suckers borne from plants with corm rot invariably show signs of decay and they are considered the primary source of infection in new plantings. There is also a possibility that nematodes can survive in roots remaining after corm harvest and subsequently invade suckers when they are re-planted; this needs to be checked. Even if it occurs, however, it is probably of minor importance compared to corm-borne spread of the disease.

Control measures. Control of the disease in the swamp environment is fraught with problems. Foremost is the method of cultivation of *Cyrtosperma* which ensures a continuous source of taro for nematode infection. At harvest, when plants are 3-5 years old, they are pulled from the swamp, and the suckers, the propagating stock of the next crop, are immediately re-planted. Rots which are already present in these suckers will enlarge as the plants mature.

Advising growers to plant only suckers free of rot is an obvious recommendation, but requires the knowledge of how long the nematode can survive in root masses from harvested plants and in soil, before it can be given with confidence.

This aspect of the disease is now being investigated.

Taro, *Colocasia esculenta*

One of the more interesting aspects of this investigation is the possible connection between corm rot of *Cyrtosperma* and that affecting *Colocasia* taro grown in swamps in Palau where *Cyrtosperma* is also present. The problem has long been recognized and both Morwood (1958) and Trujillo (1971) considered *Pythium* fungi to be the cause, with losses of 10-50%. Such rots are well known from other localities where taro are grown in wet land conditions, for instance, in Hawaii (Ooka and Trujillo 1982), Cook Islands (Anon. 1980), and Western Samoa (Kerz-Moehlendick et al. 1984) and several well-known *Pythium* pathogens have been associated with the diseases that occur (Firman 1975).

The disease in Palau and possible cause. The problem, known locally as 'obei', in the swamp at Ollei village on Babeldaop island has been investigated by the author since 1982. At that time, extensive areas of wilted plants were present in one of the two swamps at the village, and these plants had severe corm and root rots. Isolations from roots yielded *P. middletonii*, the bacterial wilt pathogen *Pseudomonas solanacearum* was isolated from corms, and low numbers of the nematode, *Pratylenchus coffeae*, were found in the roots. *Cyrtosperma* plants appeared not to be affected and so were not investigated at that time (Jackson 1983).

Control measures. The only practical control recommendation in the circumstances was to abandon taro cultivation and use the pit for *Cyrtosperma*. This was only done in parts of the pit; the rest was left fallow. The taro were removed to the second pit or planted on dryland. In an attempt to select taro with resistance to the rot problem, seed from crosses mostly with cv. Hawaii as a parent, were sent to Palau in 1984. In other countries this cultivar has shown useful resistance to *Pythium* root rot in dryland situations and in the swamps of Cook Islands where *Pythium* has become a major problem. However, in Palau all the seedlings died soon after planting.

In 1986, after a lapse of 3 years, growers at Ollei re-planted the pit and found that a majority of the plants grew well. There were one or two areas where the plants did not thrive, but this was not thought unusual. At that time the second pit was being abandoned because of disease.

It is now known that the corm rot problem occurs elsewhere in Palau and in a recent survey of growers, conducted under the auspices of the LISA (Low Input Sustainable Agriculture) taro project, corm rot was considered to be the main factor limiting production.

Palau corm rot re-investigated. The discovery in 1986 of the *Cyrtosperma* corm rot in Yap suggested that there might be an association between the two problems. And, in fact, when corms of *Cyrtosperma* at Ollei were inspected they were found to be riddled with holes, just like those in Yap (Jackson, 1986). Large numbers of *Radopholus* nematodes were extracted from the decayed areas.

Taro at Ollei will now be re-examined to determine whether *Radopholus* is present in the roots. If it is, then there is a good possibility that it is the primary cause of the problem, allowing entry of *Pythium* and other rot-causing organisms to destroy the root system and reduce the corm tissues to the foul smelling rot typical of 'obei' disease.

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USE OF SOMACLONAL VARIATION FOR ENHANCING SMUT RESISTANCE IN SUGARCANE (*SACCHARUM OFFICINARUM* L.)

STEPHEN A. FERREIRA

Department of Plant Pathology
University of Hawaii, Honolulu, HI 96822

ABSTRACT The use of somaclonal variation, or variation among seedlings produced in tissue culture from callus, was evaluated as a method of improving smut (*Ustilago scitaminea* Syd.) resistance of agronomically important sugarcane varieties. Three formerly important commercial varieties, that were no longer grown because of susceptibility to a new smut race B in Hawaii, were used in this study. The varieties H50-7209 and H59-3775 were highly susceptible and H70-0144 moderately susceptible to race B. Somaclones or seedlings produced from callus culture of the varieties were subjected to 3 cycles of selection for smut resistance. Of the 574, 1110, and 780 somaclones of varieties H50-7209, H59-3775, and H70-0144 respectively, only 6 somaclones of H70-0144 displayed greater levels of smut resistance than the variety from which it was derived. After vegetative propagation, these 6 somaclones were subjected to a more severe bud puncture inoculation test to more accurately assess smut resistance. The same somaclones were also installed in a field trial to determine if agronomic traits such as stalk diameter, height, number, and plant volume at different times during the 2 year cropping cycle of sugarcane in Hawaii were also affected by somaclonal variation. After this test, or the fourth cycle of selection, a single somaclone of variety H70-0144 was identified with enhanced smut resistance. With this more resistant somaclone, stalk diameter, height, number, and plant volume was also significantly lower than the donor clone at 8 months age. These findings suggest that more resistant somaclones can be obtained from callus culture, but that the erosion of agronomic performance makes the somaclonal variation approach to variety improvement impractical. It is possible that this problem might be overcome if larger populations of somaclones were evaluated. Further studies to validate this approach to enhance resistance to sugarcane smut are needed.

In recent years, somaclonal variation has been reported from a diverse number of important crop species. These include: tobacco, rice, oats, corn, barley, sorghum, wheat, clover, carnation, carrot, pineapple, lettuce, garlic, *Geranium* sp., *Brassica* spp., alfalfa, celery, tomato, strawberry, sugarcane, and sweet potato (Krishnamurti and Tlaskal 1974, Heinz et al. 1977, Larkin and Snowcroft 1981, Murakishi and Collins 1983, Latunde-Dada and Lucas 1983, Moyer and Collins 1983, Umbeck and Gegenbach 1983, Zong-Xiou et al. 1983, Daub 1986). This variation which is associated with plantlets regenerated from callus or protoplast cultures often occurs regularly and at high frequencies (Larkin and Snowcroft 1981, Daub 1986). The cause of this variation is not well understood, but is believed to involve chromosomal changes and rearrangements as well as point mutations. The changes are genetic and heritable (Evans et al. 1984, Daub 1986).

Consequently, plant breeders have suggested that somaclonal variation might be useful in a variety development program (Nickell 1977, Shepard 1981, Larkin and Snowcroft 1981, Daub 1986), particularly as a means of improving an agronomically desirable cultivar whose only defect might be susceptibility to disease. The studies reported herewith, were initiated to determine if somaclonal variation in sugarcane could be used to enhance smut (*Ustilago scitaminea* Syd.) resistance in sugarcane cultivars that had been recently removed from commercial use because of the discovery of a new smut race B (Comstock and Heinz 1977, Comstock et al 1983). Were it not for smut susceptibility, these high yielding cultivars might still be grown.

Materials and methods

Production of somaclonal variants. Callus cultures of three Hawaiian sugarcane varieties, H50-7209, H59-3775, and H70-0144 were produced by aseptically culturing the young meristematic tissues of actively growing shoots on MS medium (Heinz et al. 1977). After shoot initiation in culture, roots were differentiated by transferring shoots to MS supplemented with 2,4 D and plantlets were transplanted to sterile vermiculite and soil less potting mix in pots in the greenhouse. When seedling were 8 weeks old, they were transplanted in the field and allowed to grow so that vegetative cuttings of each seedling derived from the donor or mother clone could be screened for resistance to sugarcane smut.

Screening for smut resistance. Disease resistance screening was done in two ways. In the first series of screenings, a standard inoculation procedure consisted of soaking vegetative cuttings of sugarcane in a suspension of 10^6 teliospores/ml of race B for 30 minutes (Byther and Steiner 1974, Comstock et al 1983, Ferreira and Comstock 1989). Race B was used in this study because it had become the most important and prevalent race in Hawaii. Ten 18 inch vegetative cuttings, or "seedpieces" of each somaclone were inoculated, planted in the field, and assessed for smut resistance using the standard rating scheme (with 0 being highly resistant and 9 being highly susceptible) adopted by most sugarcane smut workers around the world (Byther and Steiner 1974, Ferreira and Comstock 1989). Disease ratings were made six months after planting, and again six months after ratooning the plant crop. Somaclones were subjected to three cycles of inoculation and selection for smut resistance, with up to 30 percent of the most resistant somaclones being advanced at each stage.

After 3 cycles of smut selection, the most resistant somaclones were compared to the mother or donor clones using a modified bud puncture procedure that had been developed (Ferreira 1987). In this procedure, 5-7 day old single bud cuttings of sugarcane growing in sterile vermiculite, were inoculated by puncturing the meristem region of each shoot with a dissecting needle dipped into a 10^4 teliospore suspension of smut race B. One week later, these seedlings were transplanted to the field and disease reactions assessed in the plant cane over the next 20 weeks. Ratoon smut ratings were not obtained.

Disease assessment was made by determining the percentage of stalks or tillers smutted per infected plant. The experimental design in this test was a randomized complete block design, each treatment consisted of 10 plants with 10 replications per treatment. This degree of replication was needed to determine differences in smut resistance among the somaclones.

Agronomic trials. The donor clone and its six somaclones subjected to the final or fourth cycle of smut testing were compared also in a trial assessing agronomic performance. This trial was conducted to determine if traits other than smut resistance had been affected in the selected somaclones. This field trial had a randomized complete block design, with each treatment consisting of a three line plot 15 feet long, with 6 replications.

In each plot, stalk counts were made in the center line. Also determined for 10 randomly selected stalks of the center line of the plot were: stalk length, diameter and refractometer solids of the second internode from the ground. Data was obtained at 6 and 8 months age. An estimate of cane production for the plot was obtained by calculating stalk volume as the product of stalk counts by average stalk length and average cross sectional area of stalks that were measured for diameter. Similarly, sugar production was estimated by multiplying stalk volume and average refractometer solids percent.

Results

The results of screening somaclones of three different commercial cultivars of sugarcane, each differing in their resistance to smut race B, are given in Table 1. The data indicate that somaclones with enhanced smut resistance were produced only from the donor clone H70-0144 which had an intermediate level of smut resistance. When somaclones were derived from highly susceptible donor clones such as, H50-7209 and H59-3775, resistant somaclones were not obtained. It was evident also that several cycles of testing were needed to precisely define smut disease reactions to these somaclones and to adequately assess their smut reactions.

In Figure 1, the disease progress curves for H70-0144 and its six somaclones are given. The data show that somaclone 144-37 was significantly more resistant that the donor clone, differing in both the rate of disease increase and disease maximum expressed.

When these same somaclones were evaluated for agronomic performance at 8 months age, the results in Table 2 indicate that the most smut resistant somaclone, 144-37, was the least productive somaclone as estimated by stalk volume and sugar production (stalk volume x refractometer solids). Most of the somaclones had lower stalk volume and sugar production. Since stalk number and refractometer solids were not different significantly among treatments, lower productivity of the somaclones occurred because of reduced stalk height and diameter. This suggests that the somaclones were growing less vigorously resulting in less biomass. There was no evidence to suggest that sucrose production had been reduced. An assessment of these traits at the end of the two year growth cycle is needed to determine the effect of somaclonal variation on sugar production and quality.

Discussion

Although the use of somaclonal variation as a source of resistance for potential cultivar development has reported for many crops, there exists only a few examples of cultivars or varieties produced through the use of somaclonal variation (Larkin and Snowcroft 1981, Daub 1986, Shepard 1981). The results of this study supports the notion that although the somaclonal variation is real and heritable, it does not appear to be of practical value to the breeder since multiple changes in the genome appears to occur simultaneously.

The variation associated with somaclones is attributed to chromosomal abnormalities common in cultured cells and other changes that include translocations, deletions, amplifications, and point mutations (Murakishi and Collins 1983, Thanutong et al. 1983, Evans et al. 1984). These changes are likely to be detrimental and result in genotypes of lowered productivity. This tendency appears to be true in this study since most of the somaclones were less productive than the donor clone. If the somaclonal variation approach to variety development or enhancement is to be successful, it must be integrated into a full fledged breeding and selection program. Direct use of somaclonal variation for improving on disease resistance does not appear likely for sugarcane.

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Fig. 1. Disease progress curves for H70-0144 and its six somaclones after 4 cycles of selection.

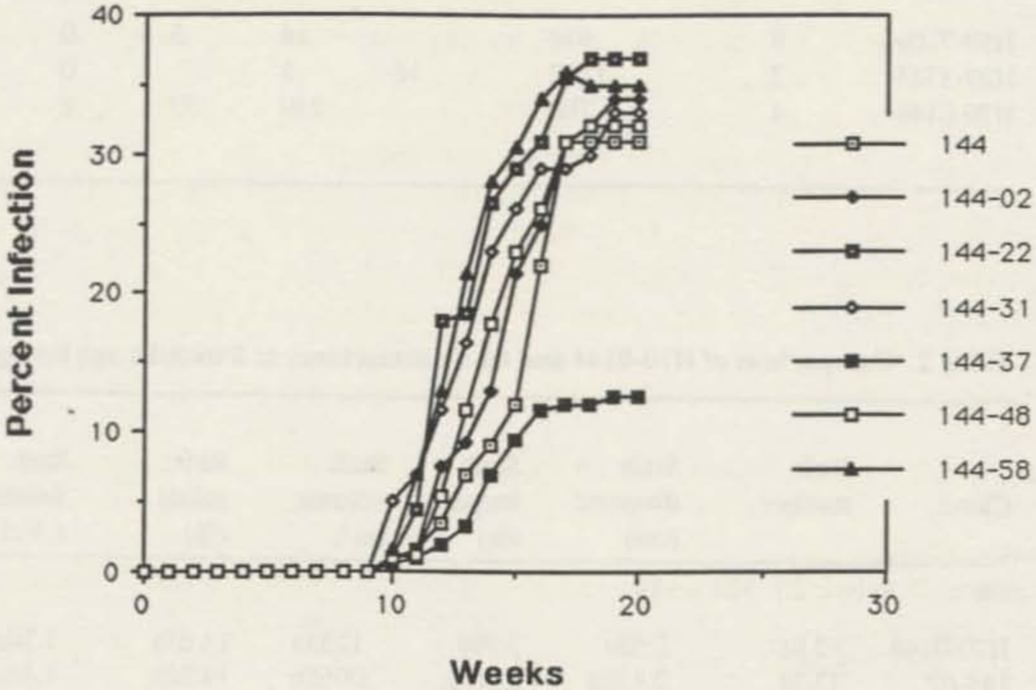

Table 1. Results of selection for smut resistance among somaclones derived from three commercial sugarcane cultivars differing in susceptibility to sugarcane smut.

Donor clone	Race B Smut Rating	No. of Somaclones Screened		Number of more resistant clones after each cycle of t selection 1	2	3	4
H50-7209	8	574		14	2	0	0
H59-3775	7	1110	16	1		0	0
H70-0144	4	780		240	59	6	1

Table 2. Comparison of H70-0144 and its six somaclones at 8 months age for agronomic traits.

Clone	Stalk number	Stalk diameter (cm)	Stalk length (m)	Stalk volume (m^3)	Refr. solids (%)	Refr. Solids x Vol
H70-0144	73.8a[1]	2.66a	2.99a	.1233a	14.65a	1.80a
144-02	72.3a	2.43cd	2.90ab	.0968b	14.90a	1.46abc
144-22	70.0a	2.52bc	2.63c	.0913b	13.40a	1.21bc
144-31	68.3a	2.42d	2.91ab	.0929b	14.23a	1.29bc
144-37	63.2a	2.52bc	2.86b	.0903b	12.58a	1.15c
144-48	71.8a	2.59ab	2.93ab	.1111ab	14.58a	1.62ab
144-58	64.3a	2.51bcd	3.01a	.0967b	13.62a	1.30bc

Means followed by the different letters in a column were significantly different at the 10% level

PLANT PROTECTION IN THE REPUBLIC OF THE MARSHALL ISLANDS

JIMMY JOSEPH

Division of Agriculture, Ministry of Resources and Development
Majuro, Republic of the Marshall Islands

ABSTRACT The Plant and Animal Protection and Quarantine Section of the Republic of the Marshall Islands of the consists of three officers who handle mainly plant quartantine but also provide pest control advice as needed. Their training needs an materials are discussed. Several reports on crops pest identification surveys have recently been done by outside agencies. At the time of the reports, the worst problem in Majuro was the coconut scale severely infesting coconut and bread fruit. Several coccinelleids were imported to Majuro which had established and were beginning to control the problem at the time of the last report. The coconut scale was also serious on Likiep. A number of new pests to the Mashall islands were also identified.

The Republic of the Marshall Islands comprises 29 corall atolls and five coral island with a total land area of only 70 sq. miles and a sea area of over 750,000 sq. miles. In the 24 inhabited atolls there are two urban centres: down-town Majuro on Majuro atoll and Ebeye on Kwajalein atoll. The urban population constitutes over 60 percent of the total population which is 43,000. The Republic lies in the Central Pacific between 4 and 19 degrees N latitude and 156 and 162 E longitude. Majuro, the capital and commercial centre is 2,000 miles from Guam and 2136 miles from Honlulu. The climate is warm and humid with an average temperature of 27°C (81°F) and little seasonal variation. The annual rainfall in the North is 70 inches compared to 170 inches in the South. Tradewinds from the northeast cool the temperatures from December through March. There is an annual dry season from February through April.

Agriculture The Division of Agriculture in the Ministry of Resources and Development is responsible for agricultural development in the Republic. This Division consists of three sub-divisions, responsible for agro-forestry, vegetable farming and livestock. The agroforestry division covers the development of coconut, pandanus, citrus, breadfruit and forestry and is concerned with traditional crop research, nursery work, coconut land rehabilitation and coconut wood utilization. The vegetable farming section collaborates with the Republic of China Technical Assistance Mission in experimental work on Laura Farm. The crops that have been produced successfully are Chinese cabbage, green pepper, chili pepper, cucumber, long beans, melon, tomato, corn, eggplant and zucchini. The livestock section is concerned with pigs and poultry. Sows and boars from New Zealand are used to improve genetic characteristics of the local pig population through cross-breeding. Imported Autrolap chicks are used to upgrade the local chickens for both egg and meat production.

The overall approach adopted by the government is to expand agricultural production by developing the private sector. Agriculture plays an important role in the economy. In 1980, over 46% of the total labor force was engaged in agriculture, fishing and forestry including subsistence activities. Products from the subsistence sector in the "money economy", mainly of copra, contribute only about one fifth of the gross domestic product reflecting the low labour productivity in the sector.

Plant and animal protection and quarantine section. The Plant and Animal Protection and Quarantine Section is under the umbrella of the Agriculture division. It consists of three full-time officers, two assigned to Majuro and one to Kwajalein/Ebeye.

1. Chief Quarantine Officer-Majuro
2. Quarantine Officer-Majuro
3. Quarantine Officer-Kwajalein/Ebeye

In addition to the above, the Chief and Assistant Chief of Agriculture perform the necessary duties when required.

The duties and responsibilities of the staff of the Plant and Animal Protection and Quarantine Section are as follows:

- Inspect all incoming vessels and aircraft entering Majuro and Ebeye/Kwajalein as a port of entry.
- Inspect travellers to the Republic and their possesions such as hand, cabin and hold luggage, etc. Confiscate and, if warranted, burn plant and other material illegaly imported into RMI.
- Collaborate with Customs and Immigration officials at airports and seaports in the effective performance of duties.
-Prepare and submit monthly reports
-Assist local farmers by providing advice relating to the control of pests and diseases.
- Perform any other duties in connection with Plant and Animal Quarantine matters.

As presently constituted, the staffing of the Section is inadequate. It is proposed to up-grade and expand it by taking the following steps:

1. The immediate recruitment and training of an officer to fill the vacancy which will be created by the retirement of the Chief Quarantine Officer at the end of 1990.
2. The recruitment and training of an officer to work with the officer at present located on Ebeye/ Kwajalein.
3. The appointment of a third officer assigneed to Majuro
4. The institution of an in-house training programme for Extension Officers in simple aspects of the prevention, control and eradication of plant and animal pests.
5. In addition to (4) above, it is also anticipated that a retired veterinarian will be available under the AESOP volunteer scheme from mid-1990 for 6 months. His duties will include training livestock and extension officers in all aspects of para-veterinary skills.

Review of work done. Following are excerpts of three surveys done by outside experts identifying pest problems in the Marshall islands.

1. Etiological Survey on Breadfruit tree pests. February-March 1989. National Pingtung Institute of Agriculture, Taiwan ROC

The Mission team surveyed Majuro, Namorik and Likiep and collected and identified many insects. Also a variety of plant pathogens were islolated and cultured on media from diseased breadfruit trees.

The principal pests found were: Transparent or coconut scale severely infesting breadfruit and coconut trees. A whitefly was also found. The team recommended the use of insecticides for spraying scale insects. Breadfruit longhorn beetles were very widespead causing the wilting of twigs and trunks and eventual death of the tree.

The Team recommended a pest management strategy which included the following measures: Cultural methods to improve the health of the trees; pruning and cutting of breadfruit trees to achieve a better tree crown; emergency insecticide spraying; effective sanitation by collecting and burning or burying leaves and branches that are obviously infected; introduction and augmentation of natural enemies; and mass production and application of entomopathogenic fungi.

This team was due to return to RMI for follow-up activities in the near future.

2. Investigation into scale problems on coconut and breadfruit and crop survey. June 1989. Dr. D. Nafus, University of Guam. Report for the South Pacific Commission.

On Majuro and Likiep, the coconut scale *Aspidiotus destructor* Signoret was infesting a wide variety of plants. The coconut scale was widely distributed on Majuro. At Laura, the undersides of breadfruit leaves were often completely covered with coconut scale. The infestation was severe all over the island from Laura to Delap. Between Delap and Rita, the infestation was light. On coconut, infestation was generally less severe than on breadfruit. As with the breadfruit, infestation was most severe in the Laura area.

Ladybeetle predators of the coconut scale were reported to have been released in January 1989 by Dr. Nelson Esguerra (College of Micronesia) in Laura and other unknown locations. The ladybeetles were found in low numbers at sites extending from around Rita to the airport. Most were found on coconut. It was recommended that *Pseudoscymnus anomalus* should be re-imported and released in the Laura area where coconut scale was most abundant.

The coconut scale was extremely abundant on breadfruit on Likiep. The pest was devastating as evidenced by dying, yellowing leaves, premature dropping of fruit, and dying limbs. The investigator stated that the RMI must make plans to deal with this scale problem, which appears to be moving from atoll to atoll, and to implement the plans without delay.

The endemic coconut red scale, *Furcaspis oceanica*, was commonly found of the undersides of leaves of coconuts and on flower spikes and fruits. It was distributed throughout the island but was uncommon or only lightly infested most trees. The investigator did not think that the overall level of infestation warranted action.

Several crops were surveyed on Majuro, viz. taro, corn, eggplant, radish, chili pepper, head cabbage, cucumber, soybean, long bean, pumpkin, sweet potato, papaya, coconut, breadfruit, banana, guava and limes. Below are a few major pests and some insects which are recent introductions to the Marshall Islands.

Sweet potato had the flea beetle *Chaetocnema confinis*, green tortoise beetle, *Metriona circumdata*, and the sweet potato weevil, *Cylas formicarius* as well as spider mites, *Tetranychus* sp. Several of these pests were present at damaging levels and the possibility of introducing bio-control agents should be considered.

On bananas, the aphid *Pentalonia nigronervosa* was found for the first time, and has the potential to transmit bunchy top virus. Extreme caution is recommended in importing any banana corms or other planting material into the RMI.

On beans, the leaf roller *Lamprosema diemenalis* was found seriously defoliating soybeans. A leafhopper, *Empoasca* sp. was found on long beans. *Aphis craccivora* was also present.

Several other new pests were found. *Pulvinaria* sp. was found on chili pepper, eggplant and other hosts including plumeria and *Morinda citrifolia*. Red wax scale *Ceroplastes rubens* was found on breadfruit in Rita and Delap on Majuro and on Likiep. Another new pest was an unidentified snail apprantly introduced into Laura area as a potential food species. It is now spreading and damaging vegetables and new seedlings.

No dacine fruit flies were found on Majuro or Jaluit.

A short survey of Jaluit also took place. Coconut scale was not present on Jaluit. *Icerya* sp. was very abundant on breadfruit and several other hosts. It was recommended that the ladybeetle *Rodolia pumila* be collected from Majuro and released. Jaluit also has a problem with termites and an ant species on Pinglep islet. The control of this ant species should be tackled as soon as possbile.

A number of recommendations were made:

Both insects moving on plant material and those hitchhiking on aircraft are entering the Marshalls in alarming numbers. Quarantine inspections at major ports of entry need to be strengthened and applied to all persons and parties.

The permit system needs to be reviewed for legal adequacy, penalties for violations, degree of use, degree of enforcement for all individuals or groups. Reinstitution of a policy of requiring aircraft to be sprayed should be considered.

A record of entry of biological control organisms needs to be maintained. As a minimum, information on the species entered, the target pest or pests, the numbers released, the release areas, and the origin of the beneficial species should be kept. This should apply to both entry into the Marshalls and movement between atolls.

A minimum level of training for quarantine officers should include a course or its equivalent in entomology, plant and animal pahology and economic botany. The possibility of sending quarantine officers to the U.S. quarantine school in Honlulu or elsewhere should be investigated. A minum of six months training is suggested. Although the training seems expensive, the introduction of a single pest can far exceed the costs of training many officers.

An individual should be designated plant protection officer. His duties should inlcude visiting and training farmers and extension staff. He should be able to identify all important currant or new pests and to receive, introduce, transfer and monitor the establishment of beneficial organisms. The individual should have a bachelor's degree in agriculture also with training in horticulture, entomology and plant pathology, and should be local and speak Marshallese.

An inter-atoll quarantine sytem should be establisehd. This can be either mandatory or voluntary inspection of plants or plant material in combination with an education programme.

3. Report on the the coconut and red scale infestation on Majuro and the outer islands. Sept 14-16, 1989. Dr. Nelson Esguerra, College of Micronesia.

Coccinellid predators on the coconut scale relased by Dr. Esguerra in August 1988 could be recovered on all parts of Majuro including Rita, which was the farthest place from the points of release. High populations of the beetles were seen on scale infesting coconuts, breadfruit, bananas and even plumeria. Coconut and breadfruit trees showed evidence of new green leaves, which was attributed to the establishment and control of the scale by the beetle.

The predators released for control of the coocnut scale were not effective against the red coconut scale. A formal request was made to Dr. Muniappan of the University of Guam to send the wasp parasite *Anobrolepis oceanica*. Dr. Muniappan planned to visit Majuro in the near future to asses the red scale problem and the possibility of controlling it.

Conclusions. The staff needs and requirement were addressed in a previous section of the paper. Additional needs of the Plant Protection and Quarantine Section are: advice on the acquisition and use of an incinerator for the destruction of prohibited plant and other material; advice on spraying techniques and material for use on aircraft; and advice on the organization of a workshop to discuss the proposed Manual of Procedures currently in draft form.

RESPONSE OF PURPLE NUTSEDGE (*CYPERUS ROTUNDUS* L.) TO SOIL SOLARIZATION

J. E. MILES[1] and R. K. NISHIMOTO[2]

[1] Micronesian Occupational College, Koror, Palau 96940
[2]Department of Horticulture, University of Hawaii, Honolulu, Hawaii 96822

ABSTRACT Purple nutsedge (*Cyperus rotundus* L.) has been called the world's worst weed. It is a serious pest in virtually every crop in every country and region in the tropics and subtropics. Glyphosate is one of the few herbicides which is effective against purple nutsedge, being translocated from aerial plant parts to the parent tubers, which it kills. It has been recommended that research into purple nutsedge control concentrate on attaining 100 percent sprouting of the tubers, to be followed by application of glyphosate.

Soil solarization is a method of weed and pathogen control pioneered in Israel in the 1970's. The technique consists of covering moist soil with clear plastic and allowing the sun to heat the soil. In two experiments conducted at Waimanalo on the island of O'ahu in Hawaii, tubers were buried in net bags at 15 centimeters soil depth and were recovered periodically to assess sprouting and emergence. The rate of sprouting and emergence increased as a result of solarization. It is concluded that solarization followed by application of glyphosate can give excellent control of purple nutsedge.

RED RING DISEASE [*RHADINAPHELENCHUS COCOPHILUS* (COBB, 1919) GOODEY, 1960] OF COCONUT: A POTENTIAL THREAT TO THE PACIFIC REGION.

G. S. GRANDISON

D.S.I.R. Plant Protection, Private Bag, Auckland, New Zealand

ABSTRACT Red ring disease of coconuts and oil palms, caused by the nematode *Rhadinaphelenchus cocophilus* is one of the most serious disorders of coconut. To date it is confined to the Caribbean, Central America, and northern South America. In Trinidad, 35% of the young coconut palms are killed by this pest while in Venezuela, 35% of the oil palms have been lost over the past 10 years.

As well as coconut, other hosts are date palm, royal palm, and oil palm.

Under natural conditions, infection of the plants can be initiated via the crown or roots. The palm weevil *Rhynocophorus palmarum* is a very important vector and is the principal means of transmitting the nematode infection. Although *R. palmarum* is not recorded from the Pacific Region other weevils (*R. schach*) or beetles (*Oryctes rhinoceros*) could be potential vectors as their habits are the same as the palm weevil.

There are two distinct symptom expressions caused by the red ring nematode. Red ring is the most characteristic symptom of coconut, by the presence of a 3 cm wide red or orange-red ring of discolored tissue about 3 to 5 cm below the trunk surface. The other symptom, "little leaf" is rarely seen in coconut palm but is common in oil palm. The leaves are erect, short and deformed with the pinnae being wiry and necrotic at the tips.

Red ring disease is a fatal disorder of coconuts and precautions must be taken to prevent the introduction of this nematode into the Pacific region.

HOST PLANT EXPANSION OF THE AGROMYZID LEAFMINER *LIRIOMYZA SATIVAE* BLANCHARD

CAROLINA and MARSHALL W. JOHNSON

Entomology Department, University of Hawaii-Manoa
Honolulu, Hawaii 96822

ABSTRACT *Liriomyza sativae* Blanchard is an important pest on vegetable crops in Hawaii and North America. Of the many crops colonized, green onion has never been reported as a preferred host plant. However, recently this species has become an important pest on green onions in the Waianae area of Oahu.

Studies were conducted to investigate the host preference behavior and immature developmental time of *L. sativae* individuals from Waianae infested green onions compared with *L. sativae* individuals infesting beans in Hawaii Kai where green onions are not grown. Results of the experiment suggest that the Waianae *L. sativae* strain had developed a preference for green onion which was not a favorable host plant for the Hawaii Kai strain. In choice tests, adult *L. sativae* flies from Waianae green onion laid eggs in both green onion and bean foliages as compared to Hawaii Kai flies which rarely deposited eggs in green onion. Immatures of Waianae strain *L. sativae* developed significantly faster in green onion that Hawaii Kai *L. sativae* flies. This study suggests that *L. sativae* has the ability to exploit new plant hosts when preferred hosts are absent from its environment.

SURVEY OF FERTILIZER USAGE IN THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

L.N. RAGUS, A.P. TUDELA, M. HOFSCHNEIDER
AND H. RICHARDS

Life Sciences/Land Grant. Northern Marianas Community College
P.O. Box 1250, Saipan, MP 96950

ABSTRACT A recent survey on fertilizer usage of farmers from Rota, Saipan and Tinian was conducted to discover the general farmer's practices in fertilizing their crops. Generally, CNMI farmers plant vegetables. They seldom use organic fertilizers due mainly to acute shortages of supplies, labor intensiveness and bulkiness in handling and application. The farmers depend heavily on commercial fertilizers, especially complete fertilizers, to replenish soil nutrients lost in crop removal. Wide variability in time, rate and method of fertilizer application among farmers was noted in all three islands surveyed. Data from cucurbit and taro farmers are presented.

With the increasing application of chemicals such as pesticides and fertilizers to the soil or plants for better crop production, pollution of the environment, especially the groundwater, is a growing concern almost all over the world. In the Commonwealth of the Northern Mariana Islands, data showing the trends in usage of fertilizers are wanting. Hence, this survey is an initial attempt to obtain pertinent information about fertilization practices for the crops commonly grown in CNMI. It is hoped this information will serve as basis for the plan of work in educating farmers on appropriate usage of fertilizers and for research agenda to minimize environmental pollution.

CNMI soils-uses and management

Saipan, Tinian and Rota have volcanic cores upon and around which limestone has been deposited. Certain soils such as those of the Banaderu, Chinen, Dandan, Luta and Takpochao series occur only over limestone. The high rainfall of the islands (80 inches per year) causes clay materials to leach into the subsoils, thus forming clay films. Clay films are most distinct in the Akina and Laulau series. The farms visited for the fertilizer usage survey are mostly situated in shallow, drained, droughty and erosion-prone soils. On Saipan, commercial farms are situated on Chacha, Chinen, Kagman, and Saipan soils. On Tinian, most of the small commercial farms are located in the Marpo Valley area, on Chinen and Dandan clays. Other farms are further north on Banaderu, Chinen, Dandan and Saipan soils. On Rota, farming is mostly on Luta soils. Most of the nearly level land on Saipan is underlain by the shallow Chinen soils. The soil types are described by the Soil Conservation Service (USDA 1989).

Irrigation is necessary to this soil as well as to the Banaderu soils. Bananas and other deeper rooted crops grow well in deeper Saipan, Kagman and Laulau soils. The plateaus of Tinian are dominated by Dandan and Chinen soils complex, which are farmed better than pure Chinen soils. Luta soils in Rota are very droughty. However, Luta soils in the mountain top area known as the Sabana are significantly more moist and cooler than Luta soils on the lower plateaus.

Chinen, Banaderu and Luta series are shallow or very shallow and are therefore droughty and restrict plant root growth and development. Mechanical mixing of limestone base into the soil also occurs during tillage.

Forms of fertilizers

The farmers surveyed differed in their use of different forms of fertilizers due mainly to the availability of materials, experience of the farmers and convenience of handling (Table 1). The data showed farmers still depend heavily on inorganic fertilizers, especially on Rota and Tinian, for crop farming. More than 10% of Saipan farmers did not apply fertilizers because their farms were newly opened. However, most farmers fertilized their crops using organic materials such as animal wastes, crop harvests, dried weeds and inorganic fertilizers such as complete (16-16-16, 15-15-15, 14-14-14, etc.). Fish emulsion was utilized by one farmer in Saipan to fertilize his crops.

Organic materials utilized. The number of farmers listed as using organic materials includes both those who use solely organic materials and those who used a combination of organic and inorganic fertilizers (Table 2). Tinian and Rota farmers left whole or parts of plants from previous crop harvest for decomposition. Tangan-tangan leaves or decaying poles and chicken manure were used in Saipan.

Inorganic fertilizers used. The number of farmers surveyed did not conform with the number utilizing the inorganic fertilizers (Table 3). This discrepancy of number was due to the practice of farmers utilizing more than one inorganic fertilizer such as a complete fertilizer and urea.

In the entire CNMI, complete fertilizers were popularly used since these were readily available in the store and were already known to these farmers.

Common fertilizer practices for crops

Even on adjacent farms, the farmers had their own way of fertilizing crops in terms of timing, method and frequencies. What was common, however, was the use of such units of measurements as handful, cup, tablespoon and teaspoon.

At the time of planting, few farmers applied fertilizer by observing the stages of plant growth. Often, the deficiency symptoms of plants such as retarded growth and yellowing of leaves served as the signal for the fertilization time. Hence, the frequencies of fertilization were dependent on these aforementioned practices.

For the fertilizer placement, the farmers generally dug a 6-8 cm (2-3 inch) hole around the plant (about 15 cm (6 inches) away from its base) and locally applied the fertilizer. A few dissolved inorganic fertilizers in water and watered the plants. When using organic fertilizers, they either broadcast them in the soil before planting or mixed them with inorganic fertilizer. This mixture was usually put in holes near the plants.

Root crops commonly grown are taro, sweet potato and yams, which are seldom fertilized. The usual practice is to fertilize the vegetable crops which are planted adjacent to rows of root crops.

In the entire CNMI, the following vegetables are commonly grown: cucumber, watermelon, green onion, tomato, eggplant, head cabbage, okra and bell pepper. Farmers from Saipan, Rota and Tinian differ in their frequency and rate of fertilizing these crops.

All these mentioned crops have been surveyed, however, only cucumber and taro are highlighted in this paper (Table 4).

Summary and recommendation

The data obtained from the fertilizer survey indicated the following:

1.- Most soils of farms surveyed are shallow to medium shallow as shown by observations of rocks reportedly unearthed from tilling these soils.

2. - Time, rate and frequencies of fertilizing crops are based on farmers' experience and observation of visually observed deficiency symptoms such as stunted plant growth and yellowing of leaves.

3. - Due to convenience in handling and ready availability, inorganic fertilizers are still preferred to organic fertilizers especially manure.

4. - The farmers who were surveyed requested additional information on fertilizing their crops.

Literature Cited

USDA - Soil Conservation Service and Commonwealth of the Northern Mariana Islands. 1989. Soil survey of the islands of Aguijan, Rota, Saipan and Tinian, Commonwealth of the Northern Mariana Islands.

Table 1. Number of farmers utilizing different forms of fertilizer for crop production in CNMI

Fertilizer Use	Rota		Tinian		Saipan	
	No.	%	No.	%	No	%
Inorganic fertilizer	8	67	5	62	13	46
Organic fertilizer	.	.	.	.	1	4
Combination of inorganic and organic fertilizers	3	25	3	38	10	36
No fertilizer	1	8	.	.	4	14
Total number	12		8		28	

Table 2. Organic materials commonly used in the CNMI farms surveyed.

Organic Materials used	Rota		Tinian		Saipan	
	No.	%	No.	%	No.	%
Crop residues	2	100	4	100	1	9
Legumes (tangan-tangan)	.	.	.	.	3	27
Manure						
Chicken	.	.	.	.	3	27
Horse	.	.	.	.	1	9
Pig	.	.	.	.	2	19
Other						
Fish emulsion	.	.	.	.	1	9
Total Numbers	2		4		11	

Table 3. Inorganic fertilizers commonly used in the CNMI farms surveyed.

Inorganic Fertilizers Used	Rota		Tinian		Saipan	
	No.	%	No.	%	No.	%
Complete fertilizer (16-16-16, 15-15-15, 14-14-14)	10	53	5	56	17	75
Ammonium sulfate	2	11	1	11	1	4
Potassium sulfate	1	5	.	.	1	4
Potassium chloride	5	26	1	11	.	.
Urea	1	5	2	22	1	4
Treble Superphosphate	.	.	.	.	1	4
10-20-20	.	.	.	.	2	9
Total	19		9		23	

Table 4. Fertilization practices for cucumber and taro crops in the CNMI

<u>CUCUMBER</u>

Location	Soil unit	Fertilization practices
Cucumber		
SAIPAN		
San Vicente	Dandan-Chinen complex 5 to 15% slopes	One tablespoon of complete 14-14-14, 15-15-15-, 16-16-16) per plant after two weeks of planting and one tablespoon of complete fertilizer per plant at flowering stage.
Marpi	Akina-Badland complex, 15 to 30% slopes	One tablespoon of complete fertilizer per plant when needed (i.e. if plants are yellowing); also place sawdust around plants and leave crop residues after harvest
Laulau	Chinen very gravelly loam, 5 to 15% slopes	No fertilizer applied
Gualo Rai	Chinen clay loam, 0 to 5% slopes	Mixing dried chicken manure with water in holes or mixing manure in the soil then broadcasting 10-20-20 over soils before planting
Kagman	Chinen clay loam, 5 to 15 % slopes	Commonly apply one handful of complete fertilizer; other practices include: One handful of dried chicken manure and complete fertilizer per plant. 2-3 tablespoons per plant three weeks after planting
TINIAN		
Marpo	Chinen very gravelly sandy loam, 0 to 5% slopes	One handful of complete fertilizer per plant
ROTA		
Chudang	Banaderu-Rock Outcrop complex, 5 to 15% slopes	Use urea (rate & time of application not mentioned)
Taro		
SAIPAN		
Kagman	Chinen clay loam, 5 to 15% slopes	No fertilizer used

Table 4 Continued. Fertilization practices for cucumber and taro crops in the CNMI

San Vicente	Dandan-Chinen complex, 5 to 15% slopes	No fertilizer used
Marpi	Akina-Badland complex, 5 to 15% slopes	Sawdust placed around the plants
Takpochao	Chinen clay loam, 5 to 15% slopes	No fertilizer used
China Town	Chinen clay loam, 0 to 5% slopes	No fertilizer used
TINIAN		
Marpo	Chinen very gravelly sandy, 0 to 15% slopes	No fertilizer used
ROTA		
Guata	Akina-Badland complex, 15 to 30% slopes	One handful of complete fertilizer per plant
Giaganea Hulo (Gagane)	Chinen clay loam, 5 to 15% slopes	No fertilizer used
Sabana	Chinen clay loam, 15 to 30% slopes	Use complete fertilizer or ammonium sulfate

EFFECT OF HURRICANE OFA ON THE BATS OF AMERICAN SAMOA

A.M. VARGO*, M. R. VARGO[1], and M. J. VARGO[1]

Land Grant Program, American Samoa Community College
Pago Pago, American Samoa 96799

ABSTRACT Three bat species of American Samoa, *Pteropus samoanensis*, *P. tonganis*, and *Emballanura semicaudata*, were seriously affected by a hurricane that devastated parts of Samoa in February, 1990. The *Pteropus* spp. are fruit bats important to the ecology of Samoa as both seed dispersers and pollinators of the rainforest. *E. semicaudata* is important in controlling mosquitoes and other insect pests. While the hurricane had killed many bats, the survivors were threatened by starvation and hunters when they neared villages in search of food. A multi-media, multi-agency effort to protect the remaining bats was undertaken to educate the public about the importance of bats to Samoa. An experiment with a sweetened rice mixture was conducted to establish an artificial diet for the fruit bats. The successful educational campaign and sweetened rice mixture proved to be a powerful combination to help ensure survival of the fruit bats. The fate of *E. semicaudata* remains uncertain.

Three species of bats inhabit American Samoa: the Samoan fruitbat, *Pteropus samoanensis*, the Tongan fruit bat, *Pteropus tonganis*, and an insectivorous bat, *Emballanura semicaudata*. Fruit bats are important to the ecology of American Samoa as both seed dispersers and pollinators of the rain forest. It is estimated that between 30 to 70 percent of rainforest plant species are bat pollinated (Cox, pers. comm.). *P. samoaensis* is diurnal and solitary, while *P. tonganus*, the more commonly seen fruit bat, is crepuscular and colonial. Both species roost in trees. The insectivorous bat is also colonial but troglodytic. Most members are thought to live in a cave near the village of Afono, Tutuila. They play an important role in controlling insect pests. According to Merlin D. Tuttle, founder of Bat Conservation International, one bat can capture up to 600 mosquitoes in an hour, eating about 3,000 insects a night (Anonymous, 1989). Bats also play a role in Samoan culture as a food, an element of superstition, and a character in legends.

During February 2-4, 1990, Hurricane Ofa struck American Samoa causing significant mortality to the bats. Craig and Syron (pers. comm.)speculate that bat mortality was due to three factors: high winds either killed the bats outright or blew them out to sea; their food sources were greatly reduced or destroyed by winds that stripped or killed the trees; they fell prey to hunters as they approached villages in search of food. Some farmers regarded the bats as pests because they fed on fallen bananas. While bats were observed to be feeding on unripe green bananas after the hurricane, this was unusual. Bats usually feed on overripe, unharvested fruit, that often serve as breeding places for fruit flies.

Recognizing the importance of the bats to American Samoa, a "Save the Bat" campaign was initiated. This paper documents the various aspects of the campaign, including media and educational efforts, and an attempt to feed the fruit bats until their natural sources of food were available.

Materials and Methods

In the 2 weeks following the hurricane, the senior author accompanied the Federal Emergency Management Agency (FEMA) agricultural team on their damage assessment survey of farms. It was then that the plight of the bats was realized. Besides dead bats in farm areas, many weak bats were barely hanging on to fallen banana plants and uprooted papaya trees. One farmer, Sosene Asifoa, captured 24 bats during the first few days following the hurricane (Asifoa, personal communication). He built a 1.25 x 1.25 x 1.25 m cage with chicken wire and fed the bats bananas, papayas and store-bought apples. Since fruit bats hang upside down to eat, wrapping their wings around the fruit, he suspended the fruit on strings attached to the top of the cage.

While some fruit bats could have survived by feeding at isolated pockets of vegetation that escaped the brunt of the hurricane, the majority were threatened by a food shortage and by hunters taking advantage of hungry bats that ventured into villages during daylight. Because *Pteropus* generally produce only one offspring per year, their ability to recoup to their pre-hurricane populations was in jeopardy.

The senior author contacted Le Vaomatua, a local environmental group, alerting its members of the situation, seeking information about bat nutritional requirements, and drawing up a tentative plan of action for "Save the Bats." Le Vaomatua sought information and funding from Bat Conservation International, and a multi-media educational effort followed. Broadcasts on radio and television informed the public about the importance of bats to the ecology of Samoa.

"Save the Bats" soon became a multi-agency cooperative endeavor. Articles and full page advertisements, sponsored by Le Vaomatua and the A.S. Department of Marine and Wildlife Resources, appeared in local newspapers. One newspaper, Samoa News, also sent an appeal over the newswires asking fruit producers in Pacific nations to donate fruit for the bats. Poetry and poster contests were sponsored by the above agencies and the A.S. Department of Education. The senior author, a Le Vaomatua member, and other representatives from the Land Grant Program of the American Samoa Community College gave a Bat Conservation International slide presentation to a meeting of village leaders. Its purpose was to provide information on the importance of bats to Samoa and to seek their assistance in curbing bat shooting at the village level. Likewise, other Le Vaomatua members visited villages and schools with this slide presentation and appeal.

With the cooperation of KVZK-TV, the local television station, a "Help Batman Save the Bats of Samoa" commercial was produced to educate and appeal to youths. Capitalizing on the popularity of the current hit movie, "Batman," letters were written to Warner Brothers Pictures and the Screen Actors' Guild in Hollywood, California, hoping to enlist the "real" Batman in this campaign. A "Wildlife Hurricane Advisory Bulletin" was prepared and distributed by the Land Grant Program. The veterinarian at the A.S. Department of Agriculture treated bats for injuries such as broken joints and torn wings. Children throughout the territory hung apples and pears in trees for hungry bats and cared for injured ones.

The continued feeding of bats became difficult as local supplies of fresh fruit diminished rapidly. Mr. Asifoa had been buying a crate of apples daily for the bats he had rescued. Several local grocers donated grapes (which were rejected by the bats) and apples when they were available. It soon became apparent that an inexpensive and readily available food source was needed if the continued feeding of the bats was to be encouraged.

An experiment was conducted to see if bats would eat freshly cooked rice sweetened with sugar. Grandulated sugar (120 ml) was dissolved in 250 ml water and poured over 1.5 l of freshly cooked white rice. One multivitamin tablet was crushed and mixed into the rice. Sugar served as a calorie source that, by mimicking the taste of fruit juice, induced the bats to feed; rice is an inexpensive, readily available carbohydrate source capable of absorbing sugar water. (Bats squeeze juice from fruit and spit out the pulp); the vitamin was added to provide supplementary nutrients.

The sweetened rice was put on a styrofoam plate suspended about 35 cm below a clothes hanger by strands of string looped through holes in the plate. By gripping the horizontal rung of the hanger, the bats could hang inverted to feed. The hanger was suspended from the top of a new room-sized wire cage Asifoa built to provide more room for the bats.

Results and Discussion

The bats ate the sweetened rice. However, the hanger and plate feeding device was unstable, resulting in an unacceptable amount of rice spilling to the ground. Mr. Asifoa next built a wire shelf suspended from the top of the wire cage and placed the plates of rice on the shelf. This proved satisfactory as the bats hung from the wire roof and fed on the rice below.

Because no information was available regarding how much a bat eats per day, Mr. Asifoa experimented with varying amounts of rice. For 24 bats, he ultimately dispensed 5 to 6 liters of sweetened rice per night. This continued for about 2 months. As the bats became stronger and more active, and the forest was nearly regenerated, he opened the cage to allow the bats free exit and access. The bats usually left the cage around 5:30 a.m. and returned around 9:30 p.m. to feed. Nearly all the bats returned each night during the first week. During the second week, only 50% to 75% of the bats returned. By the third week, which was 3 months after the hurricane, the bats ceased coming to the cage to feed.

Small groups of bats were observed again roosting in the nearby rainforest, and it was assumed that the bats were safe and surviving on their natural food sources. Morrill (pers. comm.) reports that between 3 to 6 months following the hurricane, bats abandoned their traditional roosts and established new ones closer to human habitation. Afterwards, bats returned to their rainforest roosts.

The "Save the Bats of Samoa" educational campaign was thought to be a success in protecting the fruit bats. Many inquiries were received on how to care for and feed the bats. Following the slide presentation for the village leaders, the officials confiscated sling shots used for hunting the bats. Several students did projects on bats for the Island Science Fair, one of which received national honors. Most importantly, though their populations are lower than pre-hurricane surveys, there is optimism for the gradual recovery of the fruit bats of Samoa.

The fate of the insectivorous bats is still in question. Between 2 to 4 months following the hurricane, mosquito populations increased (A.M. Vargo, personal observation). The appearance and subsequent increase in Dengue Fever, a mosquito-borne disease, was reported by local health officials. While an absence or decrease in insectivorous bats may have had some influence, other factors, such as more mosquito breeding places in hurricane-caused debris and the abnormally high rainfall during the hurricane, must also be considered.

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[1]South Pacific Academy, Pago Pago, AS

MS EXEL : A TOOL FOR AGRICULTURAL WORKERS

PHOEBE WALL

University of Guam, Guam Cooperative Extension,
College of Agriculture & Life Sciences, Mangilao, Guam 96923

ABSTRACT Often if is difficult to keep accurate records of field observations made by extension agents. Field observations, contact listings, and other types of records are needed for prioritizing one's activities in extension, as well as aiding with future research priorities. Several software packages were tried and MS Excel (for MacIntosh) was found to be the most useful. Easy manipulation of entries, timely entering of information, simplicity of use, and customized formatting were found to be the main advantages to the program. The capability of MS Excel to make tables, perform searches, sort, and re-sort data easily is quite useful for agricultural workers.

Agricultural extension agents on Guam receive a wide variety of calls on such topics as vegetable, fruit, nut, and root crops; diseases, insects, ornamentals, turfgrass, soils, homegardening, hydroponics, farm equipment, fertilizers, propagation, irrigation, plant nutrition, plant identification, weeds, and weed control. With the large number and wide variety of calls that are received by extension agents it is important to have a system for maintaining good records.

Records of field visits and phone calls can be used for a number of reasons. Records of field observations can be used to prioritize research projects. Observations made by agricultural extension agents can benefit others, such as researchers, who don't have the opportunity to visit the number of commercial agriculture enterprises and homesites as agents do. Records of plant varieties used by growers can help determine varieties that are promising and those that show poor performance. These records can also be used by new extension agents to help them become familiar with what varieties are being grown. Good records of pest occurences allows for the study of the seasonality and regionality of pests. This type of information could be quite valuable to researchers. These records can also be used by new extension agents to become familiar with which pests attack which crops.

It is useful to keep a record of individual clients' activities. Clients' records are useful in keeping track of crop and field history , as well as, previous pest problems. Since Guam is a U. S. territory agents are required to keep records of clients according to ethnic background to ensure agents don't discriminate against a particular ethnic group. Records of the number and type of calls agents receive is useful in determining the clientele extension serves.

MS Excel can be used by extension agents to assist in managing records. Agents can customize worksheets to keep track of information collected in the field such as, date, clients' name, location of the client, pest, crop pest is attacking, and name of the variety. An agent can keep customized worksheets in the office to keep track of information such as, name, ethnic background, and location of client; and date, time and topic of conversation.

Information collected by agents can easily be typed in the computer by secretaries or student help. Once the information is entered it can be sorted by subject matter. Excel automatically sorts information alphabetically. One can sort information in any manner one wishes by column.

MS Excel is a versatile program. Statistics can be run on Excel and it is transportable between both DOS machines and MacIntoshes (Apple). Excel files can easily be transferred to other programs, such as Pagemaker, for a more graphically appealing publication. Extension can utilize MS excel for making pesticide guides, planting guides, and registration forms for workshops, as well as keeping records.

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