Management of Arthropod Pests of Agriculture in the Commonwealth of the Northern Mariana Islands

A summary of information on major agricultural pests in the CNMI, with an introduction to the region's pest management issues in Micronesia.

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Located more than 5,000 km west of Hawaii, the Marianas are among the most distant of the U.S.-affiliated islands in the Pacific. The Mariana Islands were taken from the Japanese by U.S. forces in 1944 in some of the bloodiest battles of the Pacific. The Northern Mariana Islands—all of the islands except for Guam—were administered as a Trust Territory by the United States until 1978, when they became a U.S. commonwealth. In 1986, the indigenous islanders—Chamorros and Carolinians—became U.S. citizens.

Many federal programs administered by the U.S. Department of Agriculture (USDA) to protect and support U.S. agriculture are established in the Commonwealth of the Northern Mariana Islands (CNMI). These include the U.S. Cooperative Extension Service, which is administered through Northern Marianas College (NMC). I worked as an agricultural entomologist for the Cooperative Extension Service in the CNMI in 2001.

The U.S. Cooperative Extension Service is established at land grant institutions in each of the former Trust Territories of the Pacific. In addition to the CNMI, these include the Republic of Palau, the Federated States of Micronesia, the Republic of the Marshall Islands, and American Samoa. With the exception of American Samoa, all of these island groups are in the region of the western Pacific known as Micronesia (Fig. 1).

The island states of the American Pacific, which include atolls and high islands, share similar agricultural systems based on a variety of tree crops, root crops, and vegetables (Barrau 1961, Sproat 1968). They also share similar pest complexes and face comparable challenges in establishing effective quarantine and pest management programs (Nafus 1996, 1997). The Northern Mariana Islands and other parts of Micronesia are populated by a unique mix of Asian, Pacific, and New World pests (Gressitt 1954). However, no pest management program has been articulated for the region, and no pest management reference manual for Micronesia exists. A crop protection specialist attempting to design a pest management program for the diverse cropping systems of the CNMI must assemble information from diverse sources. In this article, I attempt to summarize information on major agricultural pests in the CNMI and introduce the region's pest management issues to readers who are unfamiliar with Micronesia.

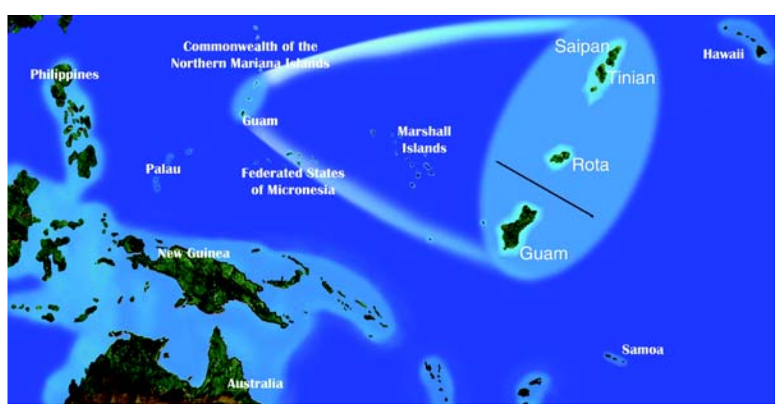

Fig. 1. This map shows the location of the U.S.-affiliated islands of the western Pacific in relation to Asia, Australia, and Hawaii. The insert shows the position of Saipan, Tinian, and Rota (CNMI) in relationship to Guam, an unincorporated U.S. territory. (Map: Jim Carr, USDA–ARS)

Guam and the Northern Mariana Islands

Much of the following information comes from work done on Guam and from work done throughout Micronesia by specialists based on Guam. Guam is the largest (549 km^2) and southernmost (144º55" E, 13º33" N) island in the Marianas chain (Young 1988). Although Guam and the CNMI are distinct states, they are unified in terms of geology, ecology, and culture. Guam is only 64 km south of Rota, and air travel connects the islands on a daily basis (Fig. 1). Arthropods introduced to one part of the archipelago have had little difficulty becoming established on adjacent islands, producing similar complexes of pest and beneficial arthropods throughout the southern islands (Mitchell 1980, Nafus and Schreiner 1989, Nafus 1997).

I have included information on pest management technology developed on Guam with the hope that it may be applicable to the CNMI, where such information is often lacking. I have similarly included information on the natural enemies of pests found on Guam, when these are also pests in the CNMI, with the assumption that the Guam record of introduced and endemic natural enemies may give some indication of what will be found in the CNMI when surveys are carried out.

The Island Environment

The islands of the CNMI are small (Fig. 1). Saipan (145º 43" E, 15º 12" N), the largest and most populated island, is about 120 k^2 and reaches 466 m at its highest point (Gressitt 1954, Young 1989). Tinian (145º 38" E, 15º 00" N), separated from Saipan by a narrow strait, is about 100 k^2 and is the flattest island (187 m at its highest point). Rota (145º 15" E, 14º 10" N) is similar in size to Tinian and is 130 km south of Saipan; the greatest elevation on Rota is 496 m. (Bowers 1950, Gressitt 1954). Of the 10 remaining islands in the archipelago north of Saipan, 2 have small homestead populations, and the rest are uninhabited.

The average daily temperature in the CNMI is about 30º C, and relative humidity ranges from 70% during the day to 90% at night (Young 1989). Mean annual rainfall is about 200 cm, roughly two-thirds of which falls from July to November (Young 1989). The tropical island chain lies directly in the path of the typhoons that form in the South Pacific each year and make their way toward Asia.

Farms in the CNMI tend to be a few hectares or sometimes a fraction of a hectare in size. Most farms in the CNMI consist of a patchwork of mixed vegetable and root crops. Larger fields on Rota may be devoted entirely to sweetpotatoes or other root crops. The soils of the Marianas are lateritic and coralline, with both sandy and clayey soils used for agriculture (Fig. 2) (Bowers 1950, Young 1989).

The economy of the CNMI is based on federal funds, tourism from Japan and Korea, and garment factories. Tourism has declined sharply since the mid-1990s because of the Asian financial crisis, and the future of the garment industry in the CNMI is uncertain. A high percentage of food consumed in the CNMI is imported. The main markets for food grown in the CNMI are local supermarkets, garment factories, and resorts. A limited amount of produce is exported to Guam, primarily from Rota.

Fig. 2. A sweetpotato field on Rota reveals the high coral content of the soil.

Entomology in the Northern Mariana Islands

The first arthropods to become established in the Mariana Islands may have been delivered from southeast Asia or other areas by air currents, floating debris, or migratory birds (Gressitt 1954). The remarkable individuals who first made the journey from southeast Asia to the Marianas by canoe 3,500 years ago probably brought arthropods with them (Pemberton 1954, Rogers 1995). Spanish, German, and Japanese colonialists brought crops and associated arthropods to the Mariana Islands from the Americas, Asia, and other parts of the Pacific during three centuries of occupation (Bowers 1950, Gressitt 1954, Marutani et al. 1997). Gressitt's (1954) comment that "the Marianas have a complex fauna of multiple origin" has become no less meaningful in recent decades. The advent of daily jet service to the Marianas from the Pacific and Asia and increased U.S. military activity in the region since the 1960s are both associated with an increase in pest introductions (Schreiner and Nafus 1986, Schreiner 1991).

Biological Control and Pesticides

Most agricultural pests in the Mariana Islands have come from elsewhere and usually arrived without their native complement of natural enemies (Townes 1946). Entomologists therefore have stressed the importance of classical biological control for the islands (Oakley 1946, Townes 1946, Bryan 1949, Pemberton 1954, Nafus 1997). Many local farmers on Saipan, Tinian, and Rota use pesticides sparingly, and the economics of farming in the CNMI do not in many cases warrant high investment in pesticides. Conditions therefore exist on some farms for natural enemies (introduced and endemic) to contribute to the suppression of pests. Because of the coralline nature of soils in the Mariana Islands, fresh water reserves may be vulnerable to pesticide contamination under certain conditions. There are sound public health reasons to emphasize biological control on the islands and pest management methods that reduce risks associated with pesticide use.

Growers in the CNMI currently rely heavily on malathion, carbaryl, and diazinon. Sales representatives from agricultural supply companies that visit the CNMI from the U.S. mainland focus on the landscaping needs of the islands' hotels and golf courses rather than agriculture. Many of the newer insecticide chemistries, such as imidacloprid and spinosad, are not available in the CNMI. (*Bacillus thuringiensis* products and some horticultural oils are available in the CNMI.) The cost of many newer products may make them unattractive to growers who farm several crops on a small scale for limited return. However, farmers in the CNMI who choose to use pesticides would benefit from a broader choice of materials for their pesticide rotations, and target-specific pesticides would enhance pest management programs for certain crops. (Insecticide recommendations for the Marianas for some of the pests discussed here are found in Nafus [1997] and Yudin and Butz [1998].)

Quarantine

The Animal, Plant, and Health Inspection Service (APHIS) of the USDA provides technical assistance and training to quarantine programs of the former trust territories from its base on Guam, as does the Secretariat of the Pacific Community (SPC), based in Fiji. In theory, the CNMI follows U.S. quarantine regulations.

Obstacles to the effectiveness of quarantine systems that have been identified in other parts of Micronesia (Nafus 1996, 1997) also exist in the CNMI. These obstacles stem from the limited ability of quarantine personnel to identify pest species and uneven application of quarantine regulations to arriving passengers and their cargo. Ornamental plants imported to the CNMI for landscaping tourist resorts present a high risk of containing agricultural pests (Schreiner 1991).

Communication

The CNMI is unique among members of the U.S. "political family" in that it controls its own labor and immigration laws. This has a direct effect on pest management programs. During the past decade, farm labor in the CNMI has become dominated by contract workers from the Philippines, Bangladesh, and mainland China. Filipino and Bangladeshi farm employees tend to work for local farm owners who have jobs off the farm (Fig. 3). Chinese farmers tend to rent land from a third party and operate independently (Fig. 4). Extension agents visiting farms in the CNMI often encounter Filipino or Bangladeshi farm workers who speak English but do not make management decisions related to the farm, or Chinese agriculturalists who make their own management decisions but do not speak English. Communication must be improved between extension agents, farm owners, and farm workers if crop protection programs are to function in the CNMI. I can illustrate this problem with specific examples.

Soon after arriving on Saipan, I visited a farm on the Kagman Peninsula where the Nepali worker showed me high densities of whitefly on cucumber. I spent some minutes speaking with him about options for whitefly management, including soaps and oils and elbowed nozzles. Eventually he interrupted me and explained that he could only follow these recommendations if his employer, a local landowner, agreed. When I asked how often he spoke

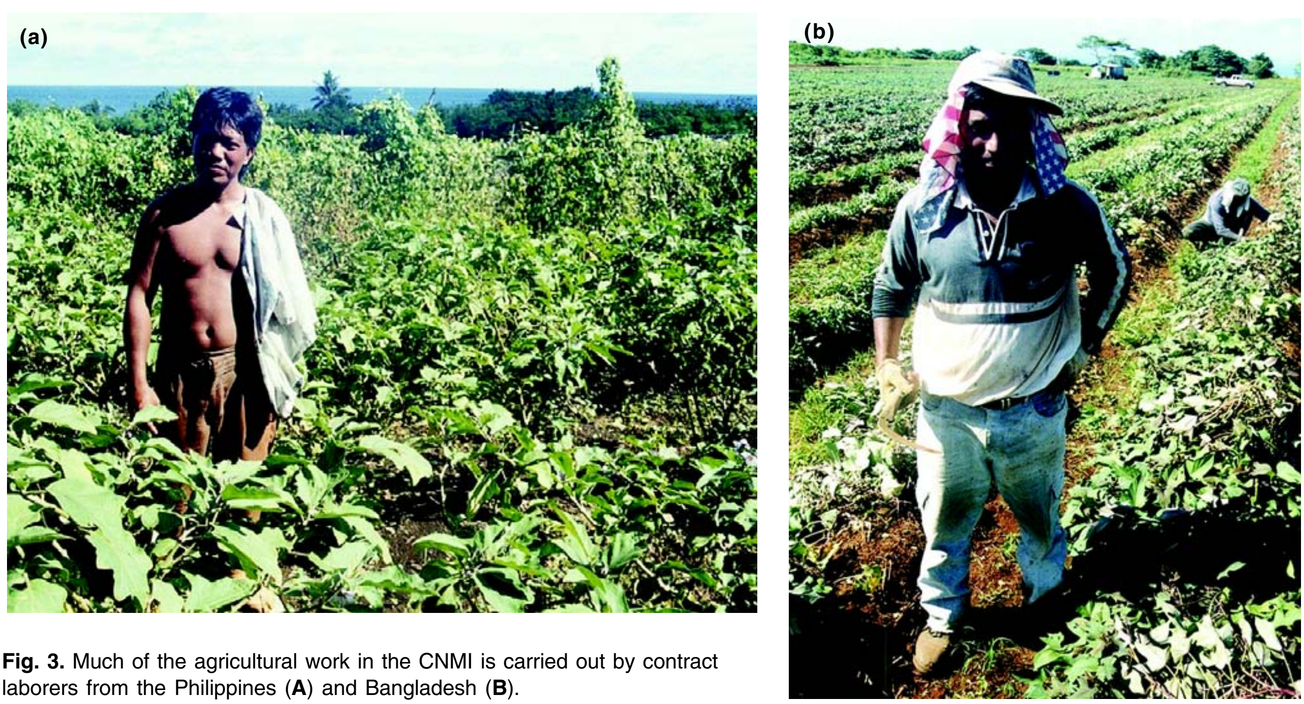

Fig. 3. Much of the agricultural work in the CNMI is carried out by contract laborers from the Philippines (**A**) and Bangladesh (**B**).

Fig. 4. U.S. extension agents in the CNMI are in the unusual position of developing outreach programs for farmers from mainland China. This couple farms on Saipan.

with his employer, he replied "Sometimes once a week, sometimes once a month." I returned to the farm on a weekly basis, but it was two months before I was able to speak with the farm owner. By that time, the Nepali worker was employed elsewhere.

Of greater concern to the public on Saipan and Tinian is alleged excessive pesticide use by Chinese contract workers. In 2001, Cooperative Extension workers on Tinian often encountered empty bottles of pesticides that had been smuggled in from Asia. There was also general concern that restricted pesticides (primarily Lannate) were being used by unlicensed farmers in the Chinese farming community. My initial visits to Chinese farms were fruitless because the workers did not understand English. All of the Chinese farmers in the CNMI are technically contract workers who must by law be employed by a local individual. In theory, the CNMI follows U.S. regulations for pesticide regulation and pesticide safety. In spite of federal and local laws requiring employers to have employees trained in pesticide use, employers I spoke with did not feel that they were responsible for the behavior of their employees. The Department of Land and Natural Resources (DLNR) is responsible for enforcing laws related to pesticide use. My discussions with DLNR field agents on Saipan and Tinian indicated that enforcement was a problem. Pesticide applicator certification training is offered in the CNMI, but only in English.

In August 2001, I began visiting Chinese farms with a Chinese national who bought vegetables for the garment factories and served as a translator. With a translator present, the Chinese farmers were quite eager to speak about their pest problems. Many empty malathion containers were visible on some of the Chinese farms, but I encountered no evidence of illegal pesticide use (Fig. 5). However, I did meet a vegetable buyer for the garment factories who admitted to selling Lannate to unlicensed farmers.

Problems with illegal use of restricted pesticides are common on the U.S. mainland. They are especially troubling in the CNMI, however, given the cultural and linguistic isolation of Chinese farmers, the fragility of the environment, and the vulnerability of fresh water sources.

Major Pests of Tree Crops

Visitors from the U.S. mainland will be familiar with banana (*Musa* spp.), coconut (*Cocos nucifera* L.), and many of the tropical fruits grown in the CNMI. Breadfruit (*Artocarpus altilis* Fosberg, Moraceae) and betelnut (*Areca catechu* L., Palmeceae) are less well known. Breadfruit is eaten throughout many of the Pacific islands (Sproat 1968). The betelnut palm produces a seed that is chewed as a stimulant throughout Micronesia. Betelnut is one of the few tree crops that is grown commercially (Fig. 6). Most other tree crops are grown for family use, and chemical treatment for pests is considered impractical.

Fig. 5. Empty malathion containers on a farm on Saipan.

The Marianas coconut beetle (Fig. 7; *Brontispa mariana* Spaeth) (Chrysomelidae) was discovered on Saipan in 1931 (Esaki 1952). By 1939, the beetle had destroyed most of the coconut plantations in the Northern Mariana Islands and with them the kopra industry on which the economy of the islands was based (Esaki 1952). Larvae and adults feed inter- and intrapinnately on the unopened spear leaf of the coconut palm, which then appears ragged as it unfolds (Lange 1950). *Tetrastichus brontispae* (Ferriere) (Eulophidae) was introduced to Saipan from Malaysia in 1948 to control *B. mariana* and became established (Lange 1950, Nafus and Schreiner 1989). However, *B. mariana* continues

Major arthropod pests of tree crops in the Commonwealth of the Northern Mariana Islands

Aleurodicus dispersus Russell Spiraling whitefly, Aleyrodidae	Citrus, coconut, mango
Aonidiella inornata Mckenzie[a] Inornate scale, Diaspididae	Banana, breadfruit, citrus, coconut
Aphis gossypii Glover[b] Melon aphid, Aphididae	Banana, breadfruit, citrus, papaya
Aspidiotus destructor Signoret Coconut scale, Diaspididae	Banana, betelnut, citrus, coconut, mango, papaya
Bactrocera frauenfeldi Schiner Mango fruit fly, Tephriditae	Breadfruit, citrus, mango
Brontispa mariana Spaeth Mariana coconut beetle, Chrysomelidae	Coconut
Coccus hesperidum L.[c] Brown soft scale, Coccidae	Banana, breadfruit, citrus, coconut, mango
Cosmopolites sordidus (Germar) Banana root borer, Curculionidae	Banana
Dysmococcus brevipes (Cockerell) Pineapple mealybug, Pseudococcidae	Betelnut, coconut
Furcaspis oceanica Lindinger Coconut red scale, Diaspididae	Coconut
Icerya aegyptica (Douglas) Egyptian fluted scale, Margarodidae	Banana, betelnut, breadfruit, citrus, coconut
Icerya purchasi Maskell Cottony cushion scale, Margarodidae	Breadfruit, mango
Ischaspis longirostris (Signoret) Black thread scale, Diaspididae	Banana, coconut, mango
Papilio polytes L. Black citrus swallowtail, Papilionidae	Citrus
Parasaissetia nigra (Nietner) Nigra scale, Coccidae	Citrus, coconut, papaya
Pentalonia nigronervosa Coquerel[d] Banana aphid, Aphididae	Banana
Phylocnistis citrella Stainton Citrus leaf miner, Gracillariidae	Citrus
Prays citri (Millière) Citrus flower moth, Plutellidae	Citrus
Saissetia coffeae (Walker)[e] Hemispherical scale, Coccidae	Banana, citrus
Tetranychus spp. Spider mites, Tetranychidae	Papaya
Vinsonia stellifera Westwood Stellate scale, Coccidae	Breadfruit, citrus, coconut, mango, papaya

Compiled primarily from Nafus (1997), but also Oakley (1946), Pemberton (1954), and Ali and Otobed (1979).
[a]Other pests of tree crops in this genus in the CNMI include *Aonidiella aurantii* (Maskell), *A. comperei* Mckenzie, and *A. eremocitri* Mckenzie.
[b]Other aphid pests of tree crops in the CNMI include *Aphis craccivora* Koch, *A. citricola* van der Goot, and *Toxoptera aurantii* (Boyer de Fonscolombe).
[c]Other pests of tree crops in this genus in the CNMI include *Coccus longulus* (Douglas), *C. mangiferae* (Green), *C. moestus* De Lotto, and *C. viridis* (Green).
[d]*Pentalonia nigronervosa* vectors bunchy top, a virus of *Musa* spp.
[e]Other pests of tree crops in this genus in the CNMI include *Saissetia nigra* (Nietner) and *Saissetia* (?) *oleae* (Bernard).

to inflict serious damage on coconut palms in the Marianas. Although coconut is no longer grown commercially in the CNMI, the palms are important components of landscaping at hotels and on golf courses.

A wide range of fruits and some vegetables in the Marianas are damaged by a complex of fruit-piercing moths (Noctuidae). *Othreis fullonia* (Clerck) is the predominant fruit-piercing moth in the CNMI (Fig. 8) (Muniappan et al. 1993). Fruit-piercing moths are unusual because it is the adult that causes crop damage (Fig. 8A). Moths are equipped with a highly sclerotized proboscis that is used to penetrate fruit. In the area of origin (the Indo-Malay region), *O. fullonia* larvae develop on plants belonging to the Menispermaceae (Waterhouse and Norris 1987). This plant family is extremely rare in the Micronesia, and larvae have adapted to develop on *Erythrina* (Fabaceae), an unrelated plant that was introduced by the Spanish.

The hymenopteran egg parasitoids *Telenomus* spp. (Scelionidae) and *Ooencyrtus* spp. (Encyrtidae) are the most important enemies of *O. fullonia* in

Fig. 6. Betelnut (*Areca catechu*) intercropped with pineapple on Tinian.

the Marianas. Denton et al. (1990) reported that about 50% of *O. fullonia* eggs collected from *Erythrina* on Guam were parasitized by *Telenomus* spp. and almost 16% were parasitized by *Ooencyrtus* spp. *Trichogramma* spp. (Trichogrammatidae) accounted for little parasitism on Guam (0.6%), but it is the predominant parasitoid of *O. fullonia* in the Federated States of Micronesia (Denton et al. 1999). Other fruit-piercing moths in the Marianas include *Pericyma cruegeri* (Butler), *Platyja umminia* (Cramer), and *Ercheia dubia* (Butler) (Denton et al. 1999).

Fruit flies. The oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Tephritidae), was introduced to Saipan from Okinawa before WWII (Esaki 1952). This fruit fly attacks a wide range of fruit crops, including citrus (*Citrus* spp.), mango (*Mangifera indica* L.), guava (*Psidium guajava* L.), papaya (*Carica papaya* L.), avocado (*Persea americana* Miller), and tomato (*Lycopersicon esculentum* Miller) (Messing 1999).

The melon fly, *Bactrocera cucurbitae* (Coquillett), was introduced to Saipan from Guam in 1943 (Fig. 9) (Esaki 1952). The melon fly is primarily a pest of cucurbits, although it also infests tomato, peppers (*Capsicum* spp.), and papaya (Hollingsworth and Allwood 2000). *Opius fletcheri* Silvestri and *O. humilis* Silvestri (Braconidae) were introduced to Guam from Hawaii in the 1930s and 1950s to control *B. cucurbitae*. It is not known whether these parasitoids remain established on Guam (Nafus and Schreiner 1989). Several parasitoids introduced to Guam from Hawaii to manage *B. dorsalis* did not become established (Nafus and Schreiner 1989).

Fig. 7. The Marianas coconut beetle (*Brontispa mariana*). (Photo: Alejandro Badilles, NMC)

Integral components of fruit fly eradication technology, developed by the USDA and now used throughout the world, were first evaluated and successfully implemented in the Mariana Islands. The oriental fruit fly was eradicated from Guam in 1965 using the sterile male technique and male annihilation (Steiner et al. 1965b, 1970). The pest was eradicated from Saipan, Tinian, and Rota that year using male annihilation alone, which was carried out using methyl eugenol bait traps treated with naled (Steiner et al. 1965b, 1970).

Melon fly was eradicated from Rota in 1965 using sterile male releases combined with protein hydrolyzate-malathion bait sprays (Steiner et al. 1965a). These islandwide fruit fly eradications were the first of their kind for a crop pest. The melon fly was reintroduced to Rota from Guam in 1981 and

Fig. 8. Fruit-piercing moth (*Othreis fullonia*). (**A**) adult (Photo: University of Hawaii); (**B**) larva (Photo: Alejandro Badilles, NMC).

Fig. 9. Melon fly (*Bactrocera cucurbitae*) on noni (*Morinda citrifolia*), Rota. (Photo: Alejandro Badilles, NMC).

continues to be a serious economic pest and barrier to crop export throughout the Mariana Islands.

The Mariana Islands remain free of the oriental fruit fly; however, the pest was introduced to Hawaii from Saipan in 1946, probably by returning soldiers (Fullaway 1949). Efforts to eradicate the oriental fruit fly from Hawaii are ongoing. Integrated management strategies for the melon fly and other fruit flies have been developed for Pacific islands (Messing 1999, Allwood et al. 2001). These include areawide methods such as sterile male technique, male annihilation with poisoned traps, and classical biological control. Growers can protect crops by bagging fruit, growing resistant varieties, and conserving natural enemies (Messing 1999, Allwood et al. 2001). Early harvest and destruction of breeding sites are key components of fruit fly management (Messing 1999, Allwood et al. 2001).

The USDA Agricultural Research Service (USDA–ARS) in Hawaii has pioneered the use of augmentoria for managing melon fly. Augmentoria are mesh tents in which post-harvest cucurbit debris is placed (Fig. 10). The mesh traps melon fly adults that emerge from the debris, but allows the escape of parasitoids. Such technology could be adapted to the small-scale farms of Micronesia. A fruit-fly monitoring program was reestablished in the CNMI in 2000 and is ongoing.

Fig. 10. The USDA–ARS in Hawaii is developing fruit fly management technology appropriate for Pacific island groups. Postharvest cucurbit debris is placed in mesh tents (called augmentoria) on this farm near Honolulu. The mesh permits the escape of fruit fly parasitoids but prevents the escape of melon fly adults.

Root Crops

With the exception of sweetpotato, *Ipomoea batatas* L. (Lam.), root crops in the CNMI only occasionally have significant reductions in yield because of arthropod pests. Taro (*Colocasia*, *Cyrtosperma*, and *Xanthosoma* spp.), yam (*Dioscorea* spp.), and cassava (*Manihot esculentum* Crantz) are attacked by a range of generalist pests including mites, scale insects, and mealybugs (Nafus 1997).

Sweetpotato production throughout the CNMI is severely affected by the **sweetpotato weevil**, *Cylas formicarius* F., and the **West Indian weevil**, *Euscepes postfasciatus* (Fairmaire) (Curculionidae) (Fig. 11). Management programs for sweetpotato weevils that have been developed at research centers around the globe are being implemented in the CNMI (Talekar 1991, Eavy et al. 2003). This program includes the use of pheromone traps for monitoring sweetpotato weevils. Crop rotation and destruction of breeding sites (sanitation) are central components of managing sweetpotato weevils (Fig. 12). The sweetpotato weevil problem in the CNMI would be substantially reduced if abandoned sweetpotato fields and postharvest crop residue were destroyed. Crop residue can be burned, disked, or fed to livestock. Obstacles to destroying sweetpotato weevil breeding sites in the CNMI include the growers' limited access to tractors and restrictions on grazing and burning in agricultural centers such as the Sabana on Rota and Kagman Peninsula on Saipan.

Generalist Pests of Vegetable Crops

Aphids. The CNMI has benefited from an active aphid biocontrol program on Guam (Pike et al. 2000, Miller et al. 2002). *Diaeretiella rapae* (M'Intosh) (Aphidiidae), which attacks the cabbage aphid (*Brevicoryne brassicae* L.), the cowpea aphid (*Aphis craccivora* Koch), and the melon aphid (*A. gossypii* Glover) (Waterhouse 1998), has

Fig. 11. Sweetpotato tuber infested with sweetpotato weevil (*Cylas formicarius*) and West Indian weevil (*Euscepes postfasciatus*), Rota.

Major arthropod pests of vegetable crops in the CNMI

Acrocercops sp. Leaf blotch miner moth, Gracillariidae	Beans
Adoretus sinicus Burmeister Chinese rose beetle, Scarabaeidae	Beans, brassicas, corn, okra
Amrasca biguttula (Ishida) Okra leafhopper, Cicadellidae	Okra, solanaceous
Anomala sulcatula Burmeister Chafer beetle, Scarabaeidae	Corn
Aphis craccivora Koch Cowpea aphid, Aphididae	Beans, cucurbits
Aphis gossypii Glover Melon aphid, Aphididae	Beans, brassicas, cucurbits, okra, solanaceous
Aulacophora quadrimaculata F. Spotted cucumber beetle, Chrysomelidae	Cucurbits
Aulacophora similis (Olivier) Orange cucumber beetle, Chrysomelidae	Cucurbits
Bactrocera cucurbitae Coquillett Melon fly, Tephritidae	Beans, cucurbits, solanaceous
Bemisia tabaci Gennadius Sweetpotato whitefly, Aleyrodidae	Bean, brassicas, cucurbits, solanaceous
Diaphania hyalinata (L.) Melon worm, Pyralidae	Cucurbits
Diaphania indica (Saunders) Pumpkin caterpillar, Pyralidae	Cucurbits
Earias vitella (F.) Spotted bollworm, Noctuidae	Okra, solanaceous
Epilachna philippinensis Diecke Philippine ladybeetle, Coccinellidae	Solanaceous
Halticus tibialis Reuter Black garden flea hopper, Miridae	Beans, brassicas, cucurbits, solanaceous
Helicoverpa armigera (Hübner) Old world bollworm, Noctuidae	Corn
Helicoverpa zea (Boddie)[a] Corn earworm, Noctuidae	Corn (?), solanaceous (?)
Leptoglossus australis (F.) Leaf-footed plant bug, Coreidae	Beans, cucurbits, okra
Liriomyza brassicae (Riley) Cabbage leafminer, Agromyzidae	Brassicas
Liriomyza sativae Blanchard[a] Vegetable leafminer, Agromyzidae	Beans (?), cucurbits (?), solanaceous(?)
Liriomyza trifolii (Burgess) Serpentine leafminer, Agromyzidae	Beans, cucurbits, solanaceous
Maruca vitrata (Geyer) Bean pod borer, Pyralidae	Beans
Myzus persicae (Sulzer) Green peach aphid, Aphididae	Brassicas
Nezara viridula (L.) Southern green stink bug, Pentatomidae	Beans, corn, cucurbits, solanaceous
Ophiomyia phaseoli (Tryon) Bean fly, Agromyzidae	Beans
Ostrinia furnacalis (Guenée) Asian corn borer, Pyralidae	Corn
Peregrinus maidis (Ashmead) Corn planthopper, Delphacidae	Corn
Plutella xylostella (L.) Diamondback moth, Plutellidae	Brassicas
Polyphagotarsonemus latus (Banks) Broad mite, Tarsonemidae	Beans, solanaceous
Spodoptera litura (F.) Cluster caterpillar, Noctuidae	Beans, brassicas, cucurbits, okra, solanaceous
Tetranychus sp. Spider mites, Tetranychidae	Beans, cucurbits, solanaceous
Thrips palmi Karny[a] Melon thrips, Thripidae	Beans (?), cucurbits (?), solanaceous (?)
Thrips tabaci Lindemann Onion thrips, Thripidae	Beans, brassicas, cucurbits, okra, solanaceous

Compiled primarily from Nafus (1997), but also Oakley (1946), Pemberton (1954), and Ali and Otobed (1979).
[a]Presence of species is suspected in the CNMI, but requires confirmation.

Fig. 12. A local farmer on Rota reduces sweetpotato weevil breeding sites by feeding debris to his livestock. (Photo: Alejandro Badilles, NMC).

been released recently on Saipan, Tinian, and Rota (R. Miller, University of Guam, personal communication). *Aphidius colemani* Viereck (Aphidiidae) has been released on Saipan and Tinian (R. Miller, personal communication) and attacks *A. craccivora* and *A. gossypii* (Waterhouse 1998). It is not yet clear whether these species have become established in the CNMI. *Lysiphlebis testaceipes* (Cresson) (Aphidiidae) was introduced to Guam in the 1970s and has become established unaided on Rota, where it is thriving (R. Miller, personal communication).

Leafminers. Leafminer damage in the CNMI can be high, particularly on crucifers (Fig. 13). Newer pesticide chemistries, such as spinosad and abermectin, that may help manage leafminers without decimating natural enemies are not available in the CNMI. Agromyzid leafminers are often suppressed by natural enemies, which tend to be suppressed by broad-spectrum pesticides such as those commonly used in the CNMI. Developing leafminer management programs for the CNMI will first require identifying leafminer parasitoids in the Commonwealth, which may vary on different host plants (Johnson and Hara 1987).

The CNMI might benefit from adapting the biocontrol programs and leafminer monitoring programs developed in Hawaii and on Guam (Johnson 1993). Considerable effort has been applied to managing *Liriomyza* spp. leafminers in Hawaii using classical biological control (Waterhouse and Norris 1987, Johnson 1993). The parasitoid *Ganaspidium utilis* Beardsley (Cynipidae) was sent from Hawaii to Guam, where it parasitizes up to 78% of leafminers on unsprayed bean (Yudin et al. 1991). Leafminer populations on Guam also are regulated by eucoilid and eulophid parasitoids that were not intentionally introduced (Schreiner et al. 1986).

Bemisia. The B biotype and Nauru biotype of *Bemisia tabaci* were collected on Saipan and Rota in 1996 by W. Leibregts, who reared *Encarsia guadeloupe* and *Eretmocerus* P2 (Aphelinidae) from whitefly larvae in the CNMI (De Barro 1997). *Encarsia nigricephala* Douzier and *Eretmocerus* spp. have been collected on Guam (Muniappan and Esguerra 1999). There is no information available on *Bemisia*-vectored viruses in the CNMI. Farm visits in 2001 revealed little evidence of geminivirus.

Fig. 14. Chinese rose beetle (*Adoretus sinicus*). (Photo: Alejandro Badilles, NMC)

Fig. 13. Leafminer damage on Chinese mustard, Saipan.

Generalist arthropod pests of vegetables in the CNMI that are not established on the U.S. mainland include the Chinese rose beetle, *Adoretus sinicus* Burmeister (Scarabaeidae) (Fig. 14), and the cluster caterpillar, *Spodoptera litura* (F.) (Noctuidae). Both of these pests originated in Asia and are established in Hawaii (Marsden 1979, Waterhouse and Norris 1987).

Chinese rose beetle. The adult Chinese rose beetle feeds on the foliage of a broad range of vegetable and ornamental crops (Marsden 1979) and can entirely defoliate large plants (Fig. 15). Larvae feed primary on decaying matter in the soil and do not cause economic damage. The Chinese rose beetle was first detected on Guam in 1949 (Pemberton 1954). *Campsomeris* (*Micromeriella*?) *marginella modesta* Smith (Scoliidae) was imported as a

Fig. 15. Taro plant skeletonized by Chinese rose beetle, Rota.

biocontrol agent from Hawaii the following year and is established on Guam (Nafus and Schreiner 1989). Several parasitoids attack the Chinese rose beetle and the Indian rose beetle (*Adoretus versutus* Harold), which causes similar damage in other parts of the Pacific (Waterhouse and Norris 1987). However, neither species is considered a good candidate for biological control (Waterhouse and Norris 1987). Laboratory trials to manage Chinese rose beetle larvae with entomogenous fungi and nematodes did not produce promising results (Tsutsumi et al. 1993).

Cluster caterpillar. *Spodoptera litura* feeds on a wide range of agronomic, horticultural, and tree crops throughout Asia and the Pacific (Hill 1983). Eggs and larvae are attacked by many natural enemies in Micronesia, but larvae sometimes escape natural control and reach damaging levels (Nafus 1997). *Telenomus nawaii* Ashmead (Scelionidae) was introduced to Guam from Hawaii in 1936 and successfully suppressed *S. litura* populations that were ravaging banana trees (Swezey 1940). In 1971, *Telenomus remus* Nixon was introduced to Guam from India for managing *S. litura* and *Spodoptera mauritia* Boisduval, a pest of turf, and became established (Nafus and Schreiner 1989). *Apanteles marginiventris* (Cresson), *Cotesia variventris* (Braconidae), and *Euplectis xanthocephalus* Girault are often reared from *S. litura* larvae on Guam (Nafus and Schreiner 1989, Muniappan and Esguerra 1999). Removing broad leaf weed hosts of *S. litura* from cropped areas may help reduce damage by the pest (Nafus 1997).

Crop-specific Vegetable Pests

Cucurbits. The two major arthropod pests of cucurbits in the CNMI are melon fly, discussed earlier, and the **orange cucumber beetle**, *Aulacophora similis* (Olivier) (Chrysomelidae) (Fig. 16). The orange cucumber beetle attacks only cucurbits, often leaving a distinctive circular feeding pattern on the leaf. Damage to cucumber, squashes, cantaloupe, and melons is often severe. Adults feed on leaves and blossoms and sometimes attack fruit directly. Larvae are root feeders. Mulching material such as black plastic may help suppress *A. similis* (Nafus 1997). Floating row covers have been used on Guam to protect watermelon (*Citrullus lanatus*) from orange cucumber beetle and aphids (Wall et al. 1994, Miller and Schlub 2001). There is little information available on natural enemies of *Aulacophora* spp. Prospects for the biological control of *A. similis* and related species are considered poor (Waterhouse and Norris 1987).

Diaphania indica (Saunders) (Pyralidae), the **pumpkin caterpillar**, is listed by Esaki (1940) and most subsequent surveyors as a pest of cucurbits in the Northern Mariana Islands. Ali and Otobed (1979) and Nafus (1997) also include *Diaphania hyalinata* (Stoll), the **melonworm**. The two species are easily confused in their larval and adult stages (Whittle and Ferguson 1987). Examination of adults or pupae will be necessary to learn the ratio and relative importance of the two species in the CNMI. *Cremastus flavo-orbitalis* Cameron (Ichneumonidae) parasitizes *Diaphania indica* on Guam (Swezey 1940).

Solanaceous Crops and Okra. The **Philippine ladybeetle**, *Epilachna vigintisexpunctata philippinensis* (Dieke) (Coccinellidae) is a pest of tomato, eggplant, and occasionally peppers in the CNMI (Fig. 17) (Chapin 1965, Vargo and Schreiner 1991). Adults and larvae feed on the leaf surface through to the opposite epidermis, which is left

Fig. 16. Orange cucumber beetle, *Aulacophora similis*, on melon, Tinian.

Fig. 17. Philippine lady beetle, *Epilachna vigintisextapunctata philippinensis*, Rota. (Photo: Alejandro Badilles, NMC).

intact (Waterhouse and Norris 1987). Philippine ladybeetles produce a distinctive feeding pattern of clustered, parallel bite marks.

The Philippine ladybeetle was first reported on Guam in 1948 and reached Saipan, Tinian, and Rota by 1952 (Maehler 1953). The eulophid *Pediobius foveolatus* Crawford was introduced to Guam from the Philippines in the early 1950s to control *E. philippinensis*. The wasp became established and parasitized about 72% of field-collected *E. philippinensis* pupae (Peterson 1955). In 1974, an Indian strain of *P. foveolatus* that completes its development in the larval stage of the host was introduced to Guam (Nafus and Schreiner 1989).

Pediobius foveolatus was introduced from Guam to Saipan and Rota in the late 1950s and from the U.S. mainland to Saipan again in 1985 (Nafus and Schreiner 1989). Chiu and Moore (1993) reported that in 1989, 80% of field-collected *E. philippinensis* larvae were parasitized by *P. foveolatus*. The Philippine ladybeetle continues to be a serious pest of solanaceous crops in the CNMI.

The **okra leafhopper,** *Amrasca biguttula* (Ishida) (Cicadellidae), often develops high populations on eggplant and okra [*Abelmoschus esculentus* (L.) Moench] in the CNMI, producing characteristic "leafhopper burn" symptoms on the leaves (Fig. 18) (Parker et al. 1995, Schreiner 2000). In the CNMI, stands of eggplant and okra are often left in the field for a year or more to allow for long-term (if diminishing) harvest. Leafhopper populations sometimes reach high levels in these stands and then attack adjacent crops that might otherwise suffer limited leafhopper damage. Growers may benefit from destroying old stands of eggplant and okra that serve as a source for leafhoppers.

Certain pubescent varieties of eggplant may reduce oviposition by leafhoppers (Schreiner 1990, 2000; AVRDC 2001). The Asian Vegetable Research and Development Center (AVRDC) is developing eggplant cultivars that are resistant to okra leafhoppers and other eggplant pests (Caasi-Lit et al. 2001). Schreiner (2000) reported that the key period to protect okra from leafhopper damage for optimum yield is 45 to 75 days after planting.

Beans. Beans are usually grown on trellises in the CNMI. Bean pods and foliage often exhibit a confusing combination of damage from mites, the cowpea aphid, leaf miners, and an unidentified mottling. Major pests of bean include the **leafmining gracillariid** *Acrocercops* sp.; the **bean fly,** *Ophiomyia phaseoli* (Tryon) (Agromyzidae); and the **bean pod borer,** *Maruca vitrata* F. (Pyralidae) (Nafus 1997). The mines produced by larvae of *Acrocercops* sp. create dead blotches on the leaves of bean plants (Fig. 19). Swezey (1940) reported that a chalcid parasitizes *Acrocercops* on Guam.

Larvae of the bean fly burrow into the stems and petioles of yard-long bean, *Vigna unguiculata sesquipedalis* (L.) Verdc.; mung bean, *V. radiata* (L.) R. Wiclz.; and pole bean, *Phaseolus vulgaris* L., causing a distinctive swelling and cracking of the stem (Nafus 1997, Waterhouse 1998). The bean fly probably originated in Asia and has been recorded as a pest of cultivated and wild legumes throughout much of the world, with the exception of Europe and the Americas (Waterhouse 1998).

The braconids *Opius phaseoli* and *O. importatus* were introduced to Hawaii in 1969 to control the recently introduced bean fly and quickly reduced its numbers (Davis 1971, 1972). If the effect of pesticides on natural enemies such as *Opius phaseoli* can be reduced, *Ophiomyia phaseoli* may be a good candidate for biological control on smaller Pacific islands (Waterhouse 1998). *Hemiptarsenus semialbiclavus* Girault (Eulophidae) and an unidentified wasp have been reared from bean fly larvae on Guam (Nafus and Schreiner 1989).

Larvae of the bean pod borer attack the pod directly or prevent pod formation of yard-long beans and pole beans by destroying flowers. *Bacillus thuringiensis* can help control this pest, if applied from the onset of flowering (Nafus 1997). The bean pod borer is pantropical; efforts to introduce parasitoids of *M. vitrata* in different regions, including Hawaii, have in many instances been unsuccessful (Waterhouse and Norris 1987).

Crucifers. In addition to *Bemisia*, *Spodoptera litura*, and *Halticus tibialis*, pests of brassicas in the Mariana Islands include the **cabbage webworm** (Fig. 20), *Hellula undalis* (F.) (Pyralidae); the **cabbage cluster caterpillar,** *Crocidolomia pavonana* (F.) (Pyralidae); the **diamondback moth,** *Plutella xylostella* (L.) (Plutellidae); **cabbage aphids,** *Brevicoryne brassicae* (L.) (Aphidae); and **leafminers** (*Liriomyza* spp.) (Muniappan and Marutani 1990, Nafus 1997, Muniappan and Esguerra 1999).

The cabbage webworm is usually a pest of young cabbage in nurseries, where it can be controlled with pesticides. Radish has been used as a trap crop to manage the cabbage webworm on cabbage (Muniappan and Marutani 1990). Prospects for

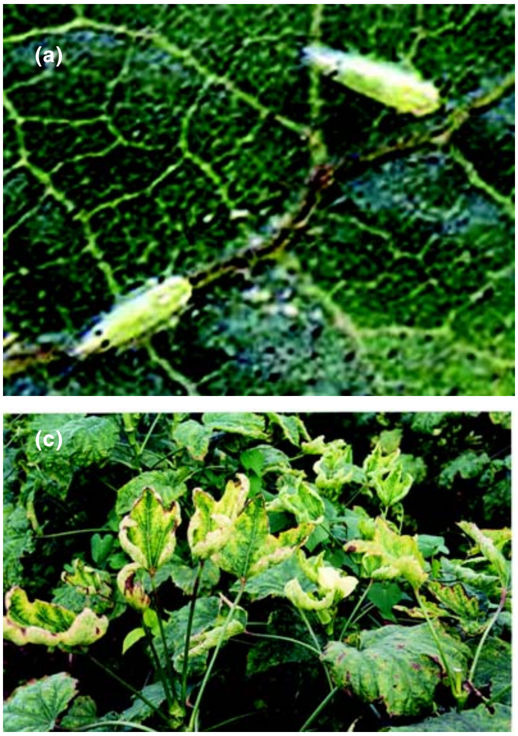

Fig. 18.
(**A**) Okra leafhopper, *Amrasca biguttula* (Photo: AVRDC). Leafhopper damage to (**B**) eggplant and (**C**) okra. In the CNMI, the practice of leaving eggplant and okra in the field for a year or more can lead to the build-up of heavy leafhopper populations.

the biological control of *Hellula s*pp. appear poor, in part because the parasitoids known to attack this group are not very host-specific (Waterhouse and Norris 1989). Destruction of crop residues and plowing to destroy pupae may be useful measures to manage the cabbage webworm and other crucifer pests, such as diamondback moth (Waterhouse and Norris 1989).

Efforts to introduce biological control agents to Guam for controlling diamondback moth have not been very successful (Nafus and Schreiner 1989, Muniappan and Marutani 1990). Parasitoids of diamondback moth known to occur in the Mariana Islands are *Trichogramma* spp., *Cotesia plutellae* (Kurdj.), and *Chelonus blackburni* Cameron (Braconidae) (Muniappan and Esguerra 1999). Nafus and Schreiner (1989) suggested that future parasitoid introductions in the Marianas target diamondback moth populations on wild hosts, once these hosts have been identified. Pesticide use on crucifers has reduced the effectiveness of parasitoids attacking diamondback moth and other pests of crucifers on Guam (Muniappan and Marutani 1990).

In Hawaii, diamondback moth on watercress (*Nasturtium officinale* R. Br.) is effectively suppressed by a combination of sprinkler irrigation and introduced parasitoids (Nakahara et al. 1986). Talekar et al. (1986) suppressed populations of diamondback moth on cabbage by intercropping with nonhosts in Taiwan. These methods may be appropriate for farmers growing crucifers in the CNMI.

Corn. The **Asian corn borer**, *Ostrinia furnacalis* (Guenée) (Pyralidae) is primarily a pest of corn in the Mariana Islands, although it also attacks *Capsicum s*pp. (Nafus 1997). Between the 1920s and the 1980s, several parasitoids were introduced to Guam and Saipan to control *O. furnacalis* (Nafus and Schreiner 1986a, 1989).

Nafus and Schreiner (1986a) surveyed *O. furnacalis* parasitoids on Guam and in the CNMI over four years. They reared *Xanthopimpla punctata* (F.) (Ichneumonidae), *Brachymeria albotibialis* (Ashmead) (Chalcididae), and *Tetrastichus (?) inferens* Yashimoto (Eulophidae) from pupae, and *Trichogramma chilonis* Ishii from

Fig. 19. Blotch mines produced on bean leaves by the leafmining gracillariid, *Acrocercops* sp., Saipan.

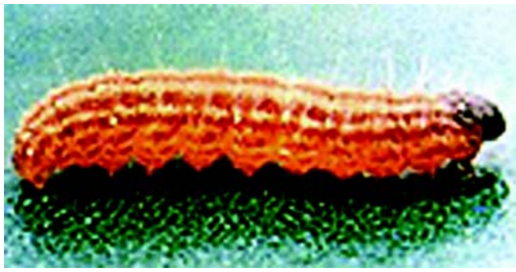

Fig. 20. Cabbage webworm, *Hellula undalis*. (Photo: AVRDC)

eggs. Overall parasitism was low (Nafus and Schreiner 1986a). *Trichogramma chilonis* is the most effective parasitoid of *O. furnacalis* on Guam (Nafus and Schreiner 1986b). Parasitism by *T. chilonis* was slightly (but not statistically) increased by intercropping corn with sweetpotato, where *T. chilonis* builds up on the **sweetpotato hawkmoth**, *Agrius convulvi* L (Sphingidae) (Nafus and Schreiner 1986b).

The **corn planthopper**, *Peregrinus maidis* (Ashmead) (Delphacidae), is a pest in the Mariana Islands (Ali and Otobed 1979). Swezey (1940) reported that the egg predator *Cyrtorhinus lividipennis* Reuter keeps the planthopper at low levels. *Anagrus* sp. was also reared from *P. maidis* eggs (Swezey 1940).

Priorities for Developing IPM Programs in the CNMI

Developing pest management programs on remote islands is not easy, but I would like to make a few suggestions.

Compile relevant information. With the exception of general pest management information that is available on the Internet, very little of the information in the proceeding summary is available in the CNMI. It was not until I moved to Hawaii in 2002 that I found there is a wealth of information on arthropods in the CNMI, much of it now on microfilm in the Trust Territory archives at the University of Hawaii. For example, there was general concern when I first arrived on Saipan about the recently "discovered" West Indian weevil in sweetpotato. A review of the literature, had it been available, would have indicated that this pest has been in the Marianas since at least the 1940s (Oakley 1946, Nafus 1997). The cropping systems of the CNMI are complex, and the pest management situation is exacerbated by the diverse origins of the pests. Resources must be assigned to assembling management information for these cropping systems and making this information available to field agents, growers, and the public.

Focus on communication. A priority for pest management programs for the CNMI must be improving the availability of information and the continuity of information. The task of communicating this information, and working with growers in general, is complicated by the cultural and linguistic diversity of the farming communities in the CNMI. English suffices as a means to communicate with most of the Chamorro, Carolinian, Bangladeshi, and Filipino farmers, but translators must be enlisted to work with the Chinese farming communities. The disconnect between local farm owners, their farm workers, and extension agents must be overcome. Many mechanisms are available for communication, but success depends on a commitment from farm owners to make themselves available and from extension agents to visit farms regularly during the cropping cycle, even during the rainy season.

Survey natural enemies. Given the potential importance of biological control in the CNMI and the rest of Micronesia, surveys of the natural enemy complexes of major arthropod pests should be a cornerstone of IPM programs in the islands. The natural enemies of crop pests should be surveyed, and their effect on pest populations assessed.

Treat Guam and the CNMI as an ecological unit. Restrictions on importing natural enemies into Guam and the CNMI should be reexamined. The literature is full of examples of arthropods, beneficial and harmful, moving from Guam to the northern islands, and vice versa. It is possible that protocols for importing biological control agents should apply to the archipelago as a whole. Area-wide pest suppression programs, such as efforts to eradicate melon fly, will have a greater likelihood of long-term success if Guam and the CNMI collaborate.

Train local residents. Resources should be directed toward training local individuals in crop protection and other aspects of agronomy. The current practice of hiring outside professionals on a short-term basis leads to a high turnover of staff and contributes to the lack of continuity of information. Local professionals will be better adapted to the "island way" of doing things and to the frustrations of working on small islands. Farmer Field School methodology, used by the Food and Agriculture Organization (http://www.fao.org/ag/agl/agll/farmspi/default.stm) and other development organizations throughout much of the tropics, may provide an appropriate model for training local field agents and farmers. Farmer Field Schools stress participatory learning methods, involve frequent meetings throughout the cropping cycle to study applied aspects of crop production, and use the field as the center of learning. The Farmer Field School approach has been used effectively in much of the developing world to teach pest identification, scouting, and other aspects of pest management.

Enhance regional collaboration. Several organizations in and around the Pacific Basin can serve as resources for developing crop protection programs in the CNMI. These include the University of Guam and APHIS on Guam, the Agricultural Development in the American Pacific program at the University of Hawaii, the USDA–ARS in Hilo, Hawaii, the SPC in Fiji, the Asian Vegetable Research and Development Center in Taiwan, and the Australian Centre for International Agricultural Research. Each of these organizations works on pests of importance to the CNMI. If crop protection specialists in the CNMI can combine local expertise with the information and technology provided by regional institutions, a highly effective pest management and quarantine service can be developed.

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