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PEST MANAGEMENT ASSESSMENT AND RECOMMENDATIONS

SUBMITTED TO:

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BELIZE: COMMERCIALIZATION OF ALTERNATIVE CROPS PROJECT
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REPORT OF THE PEST MANAGEMENT SPECIALIST

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SUBJECT: Report and Recommendations of the Short-term Pest Management Specialist

INTRODUCTION:

Belizean growers of small fruits and vegetables do not have an easy time. The cost of inputs such as heavy equipment services, small farm implements, seeds, pesticides, and fertilizers are relatively high. On the other hand, wholesale prices paid by vendors at the local markets are relatively low and often fluctuate unpredictably over time. Transport is another problem. Having ready access to a vehicle and good roads -- so that produce can be taken to the market at the proper time and in good condition -- is more the exception than the rule. These problems are commonly acknowledged and renounced by a majority of growers. Problems with crop pests* is another frequently heard complaint. Belize's humid tropical climate and lack of physical isolation from the rest of Central America put it in a vulnerable position with respect to pest problems.

Each crop in Belize is attacked by an associated group of pests. For the purposes of this report, only those pests affecting crops of interest to the Belize Commercialization of Alternative Crops Project (BCAC) will be covered. These include beans (snap), chayote (cho-cho), corn (sweet), cucurbits (cucumber, melon, squash), okra, peppers (hot), tomatoes, yams (coco or taro), papaya, and pineapples. A list of pests known to attack these crops is presented in Appendix I. The information was gleaned from the host pathogen index for Belize (Mertely, 1985) and from the index card file for the Belize National Insect Collection (BNIC), which is located at Central Farm. It constitutes the backbone of this report, but is unfortunately deficient in several respects. Information is quite sparse on four of the crops (i.e., chayote, coco yam, papaya, and pineapple). Chayote is an extreme case. The crop isn't even listed in the host-pathogen index and has only one entry in the BNIC. It was encountered only once in our survey of Orange Walk and Corozal. From this one site, three different diseases were identified. Undoubtedly many more pests of chayote exist in Belize. Hopefully these will be discovered in the upcoming farm demonstration trials, and before any commercialization of this crop is undertaken by the BCAC Project. More is known about the remaining six crops, all of which are well known and widely grown. (Note: Although little sweet corn or snap beans is cultivated in Belize, field corn and dry beans are staple crops). Even for the major crops, however, information on specific virus diseases and nematodes is quite limited. The identification of these pests require special expertise and research facilities which have not been available in Belize.

During the course of the project, "new" pests may be discovered which have not been documented in this report. Many of these pests may

*Note: In this report, the term "pest" or "crop pests" refers to both destructive insects and plant diseases.

be listed in other disease and pest indexes, particularly those covering tropical and sub-tropical areas. Several such indexes and related books are listed on pages 20-21. Single copies of these publications are available at the Plant Protection Section and/or the Agricultural Library at Central Farm.

Three weeks were allocated to the short-term Pest Management Specialist (PMS) for the completion of this report. In an attempt to determine pest problems specific to the Orange Walk and Corozal Districts, the first two weeks were spent visiting farmers in the area. Most trips were made in conjunction with two other short-term consultants (specialists in soils and irrigation) and Mr. Yung Ping Chang, Project Agronomist. In most cases, the farmers were selected by area Agricultural Extension Officers and found to be interested in cooperating with BABCO. Some of the farmers were already growing crops of interest to the project. These were examined by the PMS while the other specialists took samples and measurements needed for future farm demonstration trials. Additional pest information was gathered during two separate trips done specifically to view area crops. In all, the PMS visited 31 farms between August 11th and 22nd, inclusive. With the exception of snap beans, all crops of interest to the project were found and examined during the survey period. Few new pests (i.e., those previously unrecorded in Belize) were identified However, many pests recorded in other districts were also found in Orange Walk and Corozal.

The remaining time was spent in offices and labs. Two days were spent in microscopic examination of specimens at the Agriculture Department Veterinary Lab in Orange Walk Town. These facilities were generously made available on Saturdays by the veterinarian, Dr. Richard Brown. The remaining time was spent at Central Farm and devoted to writing and compiling data for this report.

HISTORICAL BACKGROUND

During the past 15 years, at least seven export-orientated vegetable producing ventures have sprung up in Belize. Only one is currently operating, i.e., the tomato producing operation at Baker's Ranch in Belize District. An examination of these efforts and the problems they encountered could prove valuable to the present project. In addition to Baker's Ranch, the PMS is personally familiar with three other operations which have come and gone since he began working at Central Farm in 1982. These are listed below and briefly discussed:

1. Baker's Ranch. A tomato-producing venture which commenced operations late in 1984 and continues through the present time. Mr. Thomas Garrity is the manager of the project, Caribe Farm Industries, which is located at Sand Hill in the Belize District. Some of the major plant protection problems encountered were:

   a. *Rhizoctonia* leaf blight in the nursery -- Corrected by fungicide sprays and by installing clear plastic sheeting as a roof to protect seedlings from excessive rain.

b. Leaf miners -- Severe infestations cause defoliation and consequent sunburning of fruit. Not satisfactorily controlled by many registered chemicals, although short-interval sprays with diazinon or trichlorofon helped considerably.

c. Root-knot nematodes -- Short-term control achieved by applications of nematicides such as Furadan 15G or Dasnit 15G to the soil at transplant. As pest populations build up in the future, soil fumigation or resistant varieties will need to be considered.

d. Bacterial wilt -- This difficult-to-control disease has recently been identified in production fields adjacent to the river. Crop rotation and tolerant varieties are possible control measures.

2. ----------. A cucumber and pickle growing venture located in Burrel Boom, Belize District and operated during the winter seasons of 1983-84, 1984-85, and 1985-86 (reduced operations this year). Organized and managed by Mr. Doug Fox, who runs an insurance agency in El Paso, Texas. Some pest problems encountered were weed control, Diaphania spp (i.e., pickleworms and melonworms), root-knot, nematodes, downy mildew, and mosaic virus.

3. ----------. A cantaloupe-producing project located in the New Belize and Chunox areas of Corozal District and operated during the winter season of 1983-84. Mr. Kimball Kennedy (PDAP Advisor) and Mr. John Anderson (U.S. Peace Corps Volunteer) were associated with this USAID-sponsored project. Production difficulties were primarily responsible for the failure of this project. These included:

a. Downy mildew -- Subsequently controlled by regular sprays with metalaxyl, chlorothalonil, or mancozeb.

b. Small fruit size -- Attributed mainly to cool weather conditions. The hybrid Magnum 45 was found to produce more market-grade melons than Perlita, an open-pollinated variety.

c. Marginal leaf scorch and progressive dieback of the vines during the fruiting period -- Attributed to Fusarium wilt (with some disclaimers) by Dr. Gary Simone, Extension Plant Pathologist, University of Florida. Dr. Simone was brought down to Belize on a consulting basis to analyze the problem in February 1984. His extensive report was later submitted to USAID Belize. A copy is retained in the Diagnostic File (1982-1984) at the Plant Protection Section, Central Farm. This malady, whatever its cause, led to the final collapse of the project.

4. ----------. An okra-producing venture located near Branch Mouth, Cayo District and operated during the winter season of 1982-83. Mr. Enrique DePaz of San Ignacio was one of the principals in the venture. Pests encountered were Cercospora leaf mold, root-knot nematodes, Dysdercus bug, and a virus disease causing stunting, yellowing, and ennation. Small upraised pimples or bumps on the fruit were the most serious problem, causing up to 80 percent rejection rates. These may have been caused by Dysdercus or the feeding activities of other sucking insects (e.g., aphids?).

By these accounts, one might assume that failures in pest management were primarily responsible for the demise of the ventures. This is a biased viewpoint. In cases 2 and 4, for example, all the plant protection problems could have been overcome. Both operations sent their produce to the U.S. by commercial air lines on a space available basis. Transport costs were high: profit margins were correspondingly low. If higher capitalization had permitted the development of a lower-cost shipment system, the outcome may have been different. Money would have been available for permanent technical assistance, better irrigation facilities, and the intensive application of modern pest control techniques. In case 3, plant protection problems contributed to poor product quality and eventual failure of the project. Even with the provision of expert technical assistance, leaf scorch (Fusarium wilt?) disease proved resistant to easy solution. At Baker's Ranch (Case 1), bacterial wilt disease may prove to be similarly intractable in the future.

CROP BY CROP ASSESSMENT OF POTENTIAL PEST PROBLEMS

The known pests attacking project-related crops in Belize are listed under crop headings in Appendix I. No deductions based on the relative size of the lists should be made. For example, 90 insect pests are documented for corn while only 21 insects are listed under cucurbits. Yet each crop has approximately five insects which might be considered major pests (Novelo, 1986). In the following paragraphs, potentially serious pests will be identified for each crop and comments given*. Control recommendations for most of these pests are given in the four volume series of Florida Pest Control Guides (listed on page 20). For brevity and to avoid unnecessary plagiarism, control recommendations will be provided only for pests or crops not covered in the Florida guides, or when specific information from other sources is available.

SERIOUS DISEASES OF BEANS (*Phaseolus vulgaris*)

1. Damping off, sore-shin, and other seedling diseases (*Pythium* spp, *Rhizoctonia* spp, *Fusarium* spp., etc.) -- More common in wet soils or poorly prepared fields with large quantities of undecomposed organic matter. Plant stands can be improved by good seedbed preparation, fungicide seed dressings, and planting excess seed.

2. Web blight -- A leaf blight disease which is most destructive during periods of persistent rain, clouds, and high humidity. Fungicide sprays with benomyl, captafol, or thiophanate-methyl may be necessary during such periods to save a crop.

3. Rust -- Beans planted during the normal November to December period are less damaged than those planted after January 1st. Some snap bean varieties are resistant to one or more races of rust.

4. Anthracnose -- See Florida Plant Disease Control Guide (FPDCG).

5. Mosaic virus(es) -- transmitted by seed and/or spread by aphids, whiteflies, or other insect vectors. Plant virus-free seed. Destroy broadleaf weeds (especially leguminous weeds) in and around production fields prior to planting. Varieties resistant to one or more strains of bean common mosaic virus are available.

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*Note: The PMS is a plant pathologist by training, with limited field experience in entomology. Additions or deletions to the select list of major insect pests could be made by a more highly qualified person such as Mr. Jose E. Novelo.

MAJOR INSECT PESTS OF BEANS

1. Leaf beetles (Cerotoma and Diabrotica spp) -- Larvae feed on roots and underground stem. Adults chew holes in leaves and are especially damaging to young plants. Insecticide sprays (azinphosmethyl, carbaryl, ethion, or toxaphene) may be necessary when adults are numerous. Larvae may be controlled by applying granular formulations of diazinon, disulfoton, or phorate to the soil at planting time.

2. Leafhoppers (especially Empoasca kraemeri) -- Although this species is not known to transmit bean virus diseases, heavy infestations lead to virus-like symptoms, i.e., stunting, yellowing, leaf crinkling, and poor pod set. More common under dry season conditions and on late-planted beans. See Florida Insect Control Guide (FICG) for recommended chemicals.

3. Pod borers (Heliothis virescens and others?) -- Endemic to local dry bean crops, but damage is rarely extensive enough to warrant chemical control. However, higher quality standards and possible plant quarantine ramifications may require treatment of project snap bean plots.

4. Slugs (Vaginulus plebeius) -- Infestations occur during moist weather and may be destructive to seedling stand numbers. An infrequent or sporadic problem. Jose Novelo has used slug baits to control this pest at Central Farm.

PESTS OF CHO-CHO OR CHAYOTE (Sechium edule)

Not enough information is available on this crop to give a full accounting of its major pests and diseases. In one small planting viewed at San Juaquin, Corozal District, three different diseases were identified (See Appendix I). Only one, Cercospora leaf spot, was causing significant damage. It is characterized by small (1-3 mm), roundish leaf spots with tan to white-colored centers. General browning occurred in areas of intense spotting. A regular fungicide spray program using chlorothalonil, captafol, or mancozeb should provide adequate control of all three diseases. Cho-cho fruits are susceptible to pickleworms (Appendix I). This pest should be controlled by the same insecticides recommended in the FICG for control of pickleworms in other cucurbit crops.

Cho-cho belongs to the family cucurbitaceae and may share several pests in common with other cucurbit crops. Possible problems to be anticipated are gummy stem blight, stem borers, and root-knot nematodes. Being vegetatively propagated by planting whole fruit, virus diseases may also be expected. In spite of these potential problems, cho-cho is a common native (?) backyard crop ... under these conditions, it is a reliable producer needing a minimum of special care.

SERIOUS DISEASES OF CORN (Zea mays)

1. Helminthosporium leaf blights -- Endemic on field corn in Belize, but seldom causing serious losses. Introduced varieties of sweet corn may prove to be more susceptible, although resistance has been incorporated into some varieties. Spray programs and chemicals given in the FDCG should provide adequate control, if needed.

2. Southern rust -- Occasional epidemics occur toward the latter stages of corn maturation. Controlled by the same fungicides recommended for Helminthosporium leaf blight (See FPDCG).

3. Bacterial wilt (Steward's wilt) -- This disease has not been confirmed in Belize because of the difficulties involved in isolating and identifying bacterial plant pathogens. Sweet corn is much more susceptible than field corn, although resistance has been bred into some modern cultivars. Other control measures include the use of disease-free seed and insecticides to control flea beetle vectors.

4. Virus diseases -- Symptoms suggestive of corn stunt disease (CSD) and maize mosaic virus 1 (MMV-1) are commonly observed. (CSD is actually caused by mycoplasm-like organisms or Spiroplasma sp.). These include stunting, yellowing striping of the leaves, purpling, failure to set ears, and premature death of the plant. It is conjectural whether CSD or MMV-1 are actually responsible; other viruses or combinations of viruses may be involved.

MAJOR INSECT PESTS OF CORN

1. Stalk borers -- Three species of Diatrea bore the stalks of field corn in Belize. D. saccharalis also attacks sugarcane and may be very abundant in the northern districts. Partial control may be achieved with sprays of carbaryl, methomyl, or Penncap N (an encapsulated form of methyl parathion).

2. Corn earworm -- Very common, especially on hybrid corn varieties with poor husk coverage of the upper parts of the ear. See the FICG for chemical control recommendations.

3. Fall army worm -- Damaging sporadic outbreaks may occur in fields or across limited areas. Caterpillar feeding in the whorls of young plants is characteristic. See FICG.

4. Sugarcane froghopper -- Large populations of adult froghoppers occasionally migrate from pasture grasses or sugarcane to corn. This is more likely to occur during rapid population buildups following the end of the dry season and should be less of a problem during December to March " off season". See section on leafhoppers in the FICG.

SERIOUS PESTS OF CUCURBITS

Appendix II of this report consists of an extension bulletin covering the major pests of cucurbit crops in Belize (Mertely, 1986). Five pests (i.e., pickleworms/melonworms, cucumber beetles, aphids, leaf miners, and root-knot nematodes) and four diseases (downy mildew, gummy stem blight, watermelon mosaic virus (WMV), and blossom end rot) are discussed in the bulletin. Control measures are also given and generally conform with known U.S. pesticide regulations.

Two more pests of possible concern were recognized during the project survey period. Powdery mildew disease (PM) was previously recorded on cucurbit crops in Belize, but may be more serious in northern areas than in Cayo District. PM is caused by the Oidium stage of a fungus (probably Erysiphe cichoracearum). Disease development is favored by dry atmospheric

and soil conditions, reduced light intensity (shade), good soil fertility, and succulent plant growth. The organism appears on the upper and lower leaf surfaces as patches of white powdery mold which has a dusty or fishy odor. Diseased leaves senesce prematurely, turning yellow and then brown. No resistance is available in commercial varieties of squash and pumpkin. They are more severely attacked than cucumbers and cantaloupe. Control measures consist of planting resistant varieties (of cucumbers and cantaloupe) and fungicide sprays with dinocap or benomyl. These fungicides would have to be mixed with chlorothalonil or mancozeb to maintain good control of downy mildew and other diseases.

The second pest, a vine borer, was observed in nearly every field of local winter squash and pumpkin. Plants were bored near the base where a sawdust-like excrement was seen on the ground after having been expelled from hole(s) in the vine. No adults were seen, but larval characteristics indicate it may be a beetle or weevil. However, a lepidopterous borer causing similar type of damage is described (Metcalf and Flint, 1962). Vine borers are difficult to control, being protected from insecticides after entering the stalk. Insecticide applications must begin before this has occurred or while young larvae are still feeding superficially on the plant. Sprays should be directed toward the base of the vines, using insecticides recommended in the FICG. After the last harvest, the vines should be immediately collected and burned. Deep plowing to turn under any remaining insects may also be helpful.

SERIOUS DISEASES OF OKRA (*Hibiscus esculentus*)

1. *Cercospora* leaf mold -- Characterized by the superficial growth of a brown mold on the lower surface of older leaves. Diseased leaves senesce prematurely, turning yellow and then brown. No resistant varieties are available. As of 1978, no fungicide has received EPA approval for the control of this disease ... probably because chemical companies may not be able to justify registration costs for such a minor crop. More recent information must be sought if okra is to be grown by the project.

2. Root-knot nematodes -- According to the Florida Nematode Control Guide (May 1985), "Okra is infamous for its susceptibility to root-knot nematodes ... do not plant in any field where these nematodes are likely to occur without treating the soil with a fumigant nematicide." Fumigation is an expensive operation requiring specialized equipment, chemicals and knowledge. Unfortunately, root-knot infestations were found on several farms visited during the survey period. Another section (page 16) and Appendix II will give more information on this pest which is a threat to several other crops of interest (i.e., tomatoes, peppers, cucurbits, and papaya).

3. Virus(es) -- Stunted plants with distorted mottled or chlorotic leaves are commonly seen on okra planted in Cayo District. A virus disease is probably involved. Fortunately the percent infection in any given field is usually low. This disease appears unrelated to hibiscus yellow-vein mosaic virus (Smith, 1972).

MAJOR INSECT PESTS OF OKRA

1. Sucking insects -- Small green pointed projections (pimples) on the fruit are the result of prior feeding by sucking insects. Most insects associated with okra are sucking insects in the orders Hemiptera and Homoptera (Appendix I). Aphids or cotton stainers

(Dysdercus bugs) are the most likely culprits. However this should be verified by field observations or research.

SERIOUS DISEASES OF PEPPERS (Capsicum spp)

1. Bacterial spot -- A leaf disease which is very damaging during rainy periods and is only partially controlled by copper fungicides or antibiotic sprays. Sweet peppers are extremely susceptible while hot peppers are somewhat more tolerant or resistant. The disease is seed-borne and may pop up anywhere. It was found in Little Belize and San Estephan during the project survey. A fact sheet in Appendix II provides further information. Also see the FPDCG.

2. Phytophthora root rot -- This fungus disease is most damaging following heavy rains or on heavy, poorly-drained soils. Avoid the latter, if possible. Also the removal of soil from project tractors and implements between farms may be necessary to prevent disease spread. The FPDIC and a fact sheet in Appendix II provide further information.

3. Bacterial wilt -- A soil-borne disease, like Phytophthora root rot, with similar environmental requirements and controls. Plants are predisposed to infection by the feeding activities of root-knot and other nematodes. No resistant varieties. See the fact sheet on bacterial wilt in Appendix II.

4. Virus diseases -- More prevalent on long-lived hot peppers than on relatively short-lived sweet pepper crops. Resistance to one of the most common virus diseases, tobacco mosaic virus, has been incorporated into many sweet pepper varieties, but is not available in hot pepper lines. See the FPDCG for control suggestions.

MAJOR INSECT PESTS OF PEPPERS

1. Pepper weevil -- Fruit infested by weevil larvae either abscize or are small and abnormally shaped. Crop losses exceeding 50 percent are common in unsprayed plantings. Both sweet peppers and hot peppers are attacked. Methomyl, oxamyl, or toxaphene sprays are recommended. Excellent IPM information is available (Andrews, 1984; Andrews, et.al., 1986).

2. Banded and spotted cucumber beetles (Diabrotica spp.) -- Adult leaf beetles chew holes in leaves and may defoliate young plants. Insecticide sprays using azinphosmethyl, carbaryl, diazinon, methoxychlor, etc. are occasionally necessary to protect young plants.

3. Aphids -- Vectors of cucumber mosaic, tobacco etch, and other virus diseases of peppers. However the use of insecticides to suppress aphid populations seldom results in significant decreases in virus incidence. Rarely, heavy infestations may result in direct physical damage to the crop. See the FICG for a list of recommended chemicals.

SERIOUS DISEASES OF TOMATOES (*Lycopersion esculentum*)

1. Foliar diseases (*Alternaria solani*, *Thanatephorus cucumeris*, *Corynespora cassiicola*, *Cercospora* spp., *Phyllosticta* spp., etc.) -- A number of fungal pathogens cause spotting and blighting of tomato leaves in Belize. Early blight caused by *Alternaria solani* is particularly devastating because stems and fruit are attacked, in addition to the leaves. Some market varieties are resistant to *Alternaria* stem canker and one or more leaf spot pathogens, but no claims of resistance are made for 'Tiny Tim', 'Red Cherry', and other small-fruited varieties. Nevertheless, a rigorous fungicide spray program should adequately protect even these susceptible varieties during the dry season. See the Appendix II and the FPDCG for more information.

2. Bacterial spot -- See bacterial spot on peppers. Causes a fruit spot, in addition to a leaf spot and leaf blight on tomatoes. The fruit spots are small (2 - 3 mm across), circular, brown, and seldom penetrate more than a few mm into the fruit. The disease is difficult to control during rainy weather. See Appendix II and the FPDCG.

3. Southern blight -- Caused by a soil-borne fungus which attacks the stems of numerous crops at or just below the soil line. May also cause damping-off of seedlings in the nursery if infested soil is used and not fumigated or drenched with PCNB prior to planting. In the field, wet soils and the presence of undecayed organic matter are very favorable to the disease. See Appendix II and the FPDCG.

4. Bacterial wilt -- A soil-borne disease which is particularly devastating in acid, water-logged soils. Resistant or tolerant varieties of fresh market tomatoes have recently become available (i.g., 'Kewalo' and 'BWN-21' from the U. of Hawaii and 'Topic Boy' and 'King Kong' from Takii and Know-You Seed Company, respectively).

5. Virus diseases -- At least four viruses attack tomatoes in Florida. Additional viruses (or fewer) may be present in Belize. Two sets of symptoms are commonly observed in Belize: (1) stunting, slight narrowing and chlorosis of the leaflets and reduced yield (may be caused by tobacco mosaic virus), and (2) stunting, downward curling of abnormally thickened and dark green leaflets, and very poor yields. Resistance to TMV has been bred into some varieties of fresh market tomatoes, but not the speciality small-fruited types.

6. Blossom end rot -- A physiological disorder characterized by blackening of the blossom ends of green or ripening fruit. Caused by calcium deficiency or an imbalance in the ratio of calcium to magnesium and triggered by drought stress or wide swings in soil moisture content. Certain varieties are more prone to this disorder than others.

MAJOR INSECT PESTS OF TOMATOES

1. Fruit-boring caterpillars (*Pseudoplusia includens*, *Heliothus* spp., and *Spodoptera* spp.) -- A wide range of insecticides are registered for the control of fruitworms on tomato (See the FICG).

2. Stem borer -- Tomato stems are attacked just below ground level by the larvae of a small weevil. Infested plants turn yellow and then brown with symptoms progressing from older to younger leaves. The larvae spin fiberous cocoons and pupate within the stem. Destruction of symptomatic plants is advised. Chemicals recommended in the FICG for the control of squash vine borers may also work against this pest.

3. Stink bugs (Enschistus bifibulus and other pentatomids?; Phthia picta and other coreid bugs?) -- These pests suck juices from the fruits. Tiny feeding punctures surrounded by pinkish or slightly chlorotic areas are visible on fruits as they turn red. See the FICG.

MAJOR PESTS OF COCO YAMS (Colocasia esculenta)

Though information is limited, coco yams seem to be relatively free of pests in Belize. Unlike sweet potatoes and Irish potatoes, the underground storage organs of coco yams (corms) are rarely bored or damaged by insects. Several leaf-chewing beetles are known to feed on coco yams (See Appendix I), but rarely cause significant damage. Nematodes are often associated with root crops in other countries, but no work related to nematodes on coco yams has been done in Belize.

Two diseases may be of significance. The first is a spotting or blighting of older leaves. The lesions are large (one to several inches across) and chlorotic at first. They commonly develop on the leaf margins and tend to assume a "V" or "U" shape. The central part of older lesions eventually dry up and turn brown, leaving a necrotic area bordered by a conspicuous yellow halo. These symptoms are similar to those described for Phytophthora leaf blight of taro (Cook, 1978). However, the disease is only known to occur in the Far East and the PMS has been unable to isolate Phytophthora from sick plants in Belize. A bacterial pathogen causing similar symptoms was described sometime in 1985 in Plant Disease, a journal of the American Phytopathological Society. If coco yams are selected by the BCAC project, this article needs to be located and further research done.

The second disease is a dry rot of coco yam corms. This problem is occasionally observed in corms purchased from local markets in Cayo and Orange Walk Districts. Diseased corms are progressively decayed, starting at the narrow end opposite the main bud. Internally, the rotted tissues are firm and brown in color. Externally, only a slight wrinkling of the skin is evident during the early stages of infection. The pathogen(s) involved need to be isolated and identified. Meanwhile only healthy corms should be replanted and fungicide treatment of seed corms may be desirable.

SERIOUS DISEASES OF PAPAYA (Carica papaya)

1. Anthracnose -- This fungus causes circular, water-soaked, depressed lesions on the fruit. Most serious on ripening fruit and as a post harvest disease. Controlled by fungicide sprays applied every 7-14 days during fruit development. Mancozeb, basic copper sulfate, or maneb are recommended by the FPDCG.

2. Phytophthora root rot -- Most severe in heavy, shallow, poorly-drained soils. Avoid such planting sites. Rotation to land not previously planted to papayas has been recommended (Cook, 1975). Relevant information is given in Appendix II under the heading Phytophthora Root Rot of Tomatoes and Peppers.

3. Bunchy top and dieback disease -- Refers to one or more serious diseases which limit papaya production in some areas of Belize. Both problems were observed in Orange Walk and Corozal during the survey. Bunchy-top trees are stunted or compact near the top, exhibit reduced sap flow upon wounding, and have erect, mottled, or chlorotic young leaves. The PMS has observed dieback trees only in the late stages of the syndrome. Dieback is characterized by a dying back from the apex. Diseased trees lack fruit and have only a few middle-aged leaves remaining on the tree. Above these leaves, only a bare spire remains. The disease is usually lethal. However, some farmers report that sick trees can be rejuvinated by cutting off diseased tops and relying on lateral shoots for fruit production.

   Dieback may be an advanced stage of bunchy top or the result of multiple infections by bunchy top mycoplasma and ringspot virus (Cook, 1975). Diseases caused by mycoplasma-like organisms (MLO) can be cured by treatments with tetracycline. If bunchy top in Belize is actually caused by an MLO, a symptomatic plant should be cured by two soil drenches with 100 ppm chloro-tetracycline or tetracycline hydrochloride at 3-day intervals. Complete remission should occur one to two months after treatment. This is not suggested as a practical control measure, only as a diagnostic tool. See Cook, 1972 for more information on virus diseases of papaya.

MAJOR PESTS OF PAPAYA

1. Root-knot nematode -- In newly-planted fields where papaya has not been grown before, root-knot nematodes are unlikely to seriously damage the first crop. However, soil fumigation may be necessary for subsequent crops, if root galls were commonly observed during the latter stages of the first crop. Pineapples may represent an effective rotation crop. See the Florida Nematode Control Guide (FNCG) for more information.

2. Sucking insects -- Aphids, mealy bugs, leafhoppers, and treehoppers have all been observed on papayas in Belize. Several species may be virus vectors. Spraying for their control is rarely done in local plantations but may be necessary in a commercial operation. More information on insect pests of papaya should be solicited from Florida, Hawaii, Australia, or other sources.

3. Papaya fruit fly (*Toxotrypana curvicauda*) -- Can be a serious pest papaya in Belize (Novelo, 1986).

MAJOR PESTS OF PINEAPPLE (*Ananas comosus*)

Very little is known about the pest complex attacking pineapples in Belize. One extension bulletin has been published, but much of the information was taken from outside sources (Tzul, 1985). Root rots and butt rots are common, especially in high rainfall areas and in poorly drained soils. They may be caused by a number of different fungal

pathogens, e.g., Phytophthora, Pythium, Rhizoctonia, Ceratocystis, etc. The specific controls depend upon which organisms(s) are involved, but in general, fungicide dips prior to planting are often recommended. Various types of fruit rot are also common, but no investigations have been made in Belize to identify the causal agents. Pineapples are frequently planted on marl-based soils in Belize, although the plant is better adapted to less alkaline soil types. Yellowing of plants due to micronutrient deficiencies is the result. However yellowing may also be caused by root rots, butt rots, nematodes, etc.

Mealybugs occasionally infest the roots and fruit of pineapples in Belize. 'Smooth Cayene' is more susceptible than the local 'Sugar Loaf' variety (Tzul, 1985). Heavy infestations can result in stunting, bronzing or redding, and loss of turgor. This condition, known as "mealybug wilt", is not commonly observed here. Mealybugs are often carried from plant to plant and nurtured by attendant ants. The use of insecticide sprays or poison baits to kill the ants is sometimes recommended. Diazinon, malathion, or methyl parathion sprays will control above ground populations of mealybugs.

Birds, possoms, lizards, and other vertebrates eat ripening pineapple fruits and may be serious pests.

SUITABLE AND UNSUITABLE CROPS: THE PEST MANAGEMENT PERSPECTIVE

Any crop which has been successfully exported in the past should be a viable choice for the project. These include slicing tomatoes, sweet peppers, okra, squash, cucumbers, and pickles. Crops which are commonly found in local markets can also be assumed to have manageable pest problems. These include yard-long beans (Vigna unguiculata var. sesquipedalis), chayote, coco yams, green (field) corn, habanero peppers, watermelons (plus local varieties of squash and pumpkin), and pineapples -- in addition to the crops listed above.

Several crops of interest to the project do not have a history of local cultivation or export. These crops should be viewed with some suspicion from the pest management perspective. Many exotic crops have been planted by enterprising Belizean farmers over the years. Some were productive, but failed to find favor with the consumer. Snap beans (Phaseolus vulgaris) are a case in point. Consumers were unfamiliar with the use of green beans as a vegetable. Moreover, few had refrigerators which greatly enhance the shelf life of this crop. As the general standard of living improves, snap beans are becoming more common in local markets. Dry bean cultivars of P. vulgaris are widely grown in Belize and have no insurmountable pest problems. The same is likely to be true for snap beans. However, pod borer infestations should be anticipated because of the relatively soft pod produced by snap bean cultivars. Imported varieties may also be less tolerant of virus diseases than native dry beans.

Farmers have found it difficult to produce other exotic crops, frequently because of problems with pests. Sweet corn may fall into this category. The PMS has rarely observed this crop in Belize. Most of his information is second hand. However, there are certain consistencies in farmer reports about the crop. Sweet corn cultivars may be much more susceptible to insect pests and virus diseases than local varieties of

dent corn. Chemical control programs could probably be developed to suppress damage by stalk borers, earworms, and various insects which feed on the silk or leaves. However these would add to the production costs of what is already a low margin crop and may create residue problems. Sweet corn could be tested during the early demonstration screening phase of the project. However, it may prove difficult to produce a quality crop because of problems with insects and diseases.

Cantaloupes are only found in season on the Belizean market, while honeydew melons are rarely produced. Both crops are considerably more susceptible to downy mildew disease and melonworms than cucumbers and watermelons. However, watermelon crops in all major producing areas have been severely affected by watermelon mosaic virus over the past several years. No adequate control measures exist for the disease at the present time. In rainy season variety trials at Central Farm, Improved Tam Honeydew was more seriously affected by wet soil conditions than commercial varieties of cantaloupe (Mertely, 1984). It may have a stronger preference for light, well-drained soils. 'President', a zucchini hybrid, and 'Gold Crest', a yellow squash hybrid, were also tested. Both varieties proved extremely susceptible to pickleworms and several diseases, e.g., downy mildew, powdery mildew, and mosaic virus(es). Judging by field observations, local varieties of squash and pumpkin are much less bothered by these pests. On the other hand, local varieties are quite vulnerable to the unidentified vine borer which was discovered during the survey. Commercial varieties -- with their thick soft stems -- may be even more badly damaged, although this is purely speculative.

The leaf scorch problem encountered by a previous cantaloupe project in Little Belize does not bode well for this crop as a potential winter export. Assuming Fusarium wilt was responsible for the disease, some wilt resistant varieties of cantaloupe are available. However, this resistance may not be effective against the species of fungus isolated by the project consultant and implicated with the disease. Cantaloupes (and presumably honeydew melons as well) are also quite sensitive to cool temperatures which occur with the passage of cold fronts between January and March. Slower growth and the production of poorer quality fruits may occur in early planted crops which mature during this period. A slow growing crop is also exposed for a longer period of time to insect pests and to progressive deterioration by foliar pathogens and virus diseases. If these crops are to be grown for the project, several varieties (including one or two with Fusarium wilt resistance) should be tested during the 1986-87 season. Avoid planting too early i.e., before December 1st.

Cherry tomatoes are rarely, if ever, marketed in Belize. This may be partly due to consumer preference for slicing types. However, it should be borne in mind that no resistance to diseases or nematodes has been incorporated into these speciality varieties. They may be much more delicate than conventional varieties from the plant protection viewpoint. Under dry season conditions, control of leaf diseases can be maintained by regular applications of chlorothalonil or mancozeb. If bacterial spot is present, copper hydroxide or basic copper sulfate should be added to one of the main fungicides (See the FPDCG). Resistance to Alternaria stem canker, root-knot nematodes, and tobacco mosaic virus is valuable under Belizean conditions, and may be sorely missed in cherry tomato varieties.

The supply of papayas to local markets is fairly steady, especially during the dry season. This production coming from areas or farms which seem to have escaped serious problems with bunchy top and/or dieback disease. Both diseases were observed in Orange Walk and Corozal Districts. In Cayo District, where they are fairly widespread, local supplies are unsteady and relatively high priced. Research into this problem needs to be done if papayas are to be grown on a large scale for export. Field observations should be made to record the exact symptoms and progression of disease in the field. Also, the confirmation of mycoplasm involvement, either by direct microscopic observation or treatment with chlortetracycline, should be made. A computerized search of relevant data bases should be made using key words such as papaya (or Carica papaya), bunchy top, MLO, dieback, etc. Finally expert advice should be sought from Florida, Hawaii, or other papaya producing areas.

WEEDS

Because of a lack of formal training in weed science, the PMS is unable to give proper consideration to this critical aspect of pest management. It cannot be over emphasized that weeds are serious plague to Belizean farmers. The costs of weed control either by mechanized cultivation, chemical weeding, or hand labor represent a significant portion of production costs. Reductions in yield, crop longevity, and fruit quality resulting from poor weed control are commonly observed on Belizean farms.

Land preparation is a critical aspect of weed control. Ideally land should be plowed early in the dry season and further refined shortly after the arrival of rains. If this is done properly and planting is done shortly thereafter, good weed control is maintained for at least a month and sometimes longer. Little additional weeding would be required for most field crops since weed control during the critical early stages of plant growth is most essential. Weed control requirements are more critical in vegetable crops. Moreover, dry season tillage has little relevance to project vegetable crops which will be planted towards the end of the rainy season in November, December, and January. It would be ill advised to try to convert land from unimproved pasture to vegetable production in the space of a few months time. Assuming good weed control is maintained, weeds would be much more manageable if at least one cycle of corn, sorghum, or other competative field crop were grown prior to putting in vegetables. If pasture land is to be used, the following steps are suggested: (1) bushhogging, (2) permitting regrowth for a period of several weeks, (3) Spraying with glyphosate or other systemic broad-spectrum herbicide, (4) Plowing and harrowing or discing after an appropriate waiting period (one week when glyphosate is used), (5) Permitting plant residues to decompose for at least several weeks (to reduce problems with damping off and Southern blight disease), (6) Rotovating ... combined with the incorporation of an appropriate preemergence herbicide (if available), and (7) planting.

According to Mr. Harry Parham* a short list of serious weeds in Belize should include carpet grass (Axonopus spp.), nutgrass (Cyperus rotundus and other Cyperus spp.), Bermuda grass (Cynodon dactylon), broom weeds (Sida spp.), sensitive plants (Mimosa spp.), hierba martin (Hyptis spp.), and Lippia nodiflora. Many other species are serious agronomic pests. Some of these are pictured and described in two books

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(Camacho, R. R. 1979; and Garcia, J. G. L., 1975). Herbicide recommendations for specific crops are given in the Florida Weed Control Guide (IFAS, 1985-revised).

The nutgrass problem, where it occurs, is particularly vexing for Belizean vegetable growers. Cyperus spp. are little suppressed by cultivation and almost impossible to eradicate by means short of soil fumigation. Shade and drought suppress the weed. This may be one reason why crops which are fast growing and produce heavy shade are recommended for nutgrass infested areas in some countries (William, 1976). These include chayote, kudzu, okra, sweet potato, and soybeans. Farmers may also resort to spot watering and fertilization. Enormous numbers of Cyperus rhizomes and tubers may be present in infested soils. These propagules are easily transported in soil accompanying nursery stock and clinging to implements. For this reason, project tractors and cultivation equipment should be cleaned free of soil between farms. Fumigation of project seedbeds, preferably with methyl bromide, is advised if nutgrass is present in the nursery area.

PESTICIDES AND THEIR USE

A. Pesticide Availability

During the past four years, the PMS has seen a wide variety of crop protection products on the shelves of local farm stores. Most of these are listed in Appendix III. Insecticides are especially well represented. Fungicides are less so although benomyl and one or more representatives of the copper and dithiocarbamate groups are usually stocked. The selection of nematicides is poor, but carbofuran is easily obtained at most times. The range of available herbicides is skewed toward products used on beans, citrus, cocoa, corn, and sugarcane. Selective herbicides for use on vegetable crops are poorly represented. The retail cost of these chemicals is relatively high. All are imported. The Belize pesticide market is small, a fact which encourages relatively high markups. In addition, duties are imposed. Fungicides are taxed at a 25 percent rate, insecticides and herbicides at 15 percent, and fertilizer at 5 percent.

B. Sources of Agrichemicals

Four companies or retail stores import the bulk of agricultural chemicals into Belize. Prosser, Ltd. imports most bulk fertilizers and is the local distributer for DuPont and Monsanto. Hofius is the distributor for Bayer, Dow Chemical, and Ciba Geigy, but maintains a limited range of chemicals at its store. The same can be said for the agricultural division of Brodies which distributes ICI and May & Baker products. Central/Northern Agriculture Service is not the sole distributor for any major chemical company, but does maintain limited supplies of a wide variety of agrichemicals.

Guatamala and Mexico are other sources of agrichemicals. Individual farmers and some farm stores frequently purchase pesticides from vendors in the cross-border villages of Melchur and Chetumal. Prices are cheaper there, especially for products which are manufactured or formulated in those countries. Bayer and Ciba Geigy lines are particularly well represented. Unfortunately, the small cross-border stores may be irregularly supplied with inventory. Availability is also affected by changing customs policies. The larger pesticide distributors in Belize

frequently deal with subsidiaries of major chemical companies in Guatamala and Mexico. These transactions are affected by politics, currency exchange problems, and export policies as well.

C. Level of Pest Management

Commercial vegetable and fruit operations in the United States are characterized by the use of specialized machinery, sophisticated pest management programs, and heavy use of agrichemicals. A competative export operation in Belize would also require some of this technology. But the question arises: Which of these inputs or techniques will be effective and economic in Belize? Local farmers do not know because they have traditionally grown their crops under much lower levels of management. The PMS also does not know because new crops, new varieties, large acreages, and irrigation will be introduced with the program. New, unpredicted pest problems will inevitably occur. Faced with these uncertainties and the pressures to produce impressive results early in the program, the temptation will be to use pesticides intensively from the start. Fungicides, insecticides, and nematicides may be applied routinely or on a regular schedule, regardless of the actual need of a particular crop at that particular location and time. A use-as-needed approach might be more beneficial in the long run.

Some crops will require routine pesticide applications to combat known problems. This is especially true for diseases. Most above-ground diseases are difficult to control after becoming well established. Some crops which will require regular applications of broad spectrum fungicides are snap beans, chayote, sweet corn(?), cucurbits, okra, tomatoes, and papaya. Good protection is especially needed for crops grown in seedbeds, where crowded conditions and high humidity favor disease development. Copper fungicides or antibiotics should be applied to pepper seedlings in the nursery as a purely precautionary measure against bacterial spot disease. To combat root-knot and other nematodes, granular nematicides should be used on those farms where the nematodes are known to exist, if susceptible crops are being grown. Most crops under consideration are hosts to one or more species of root-knot nematodes. However, it is probable that snap beans, sweet corn, and nematode-resistant varieties of tomatoes will not be seriously damaged by them. Pineapples and coco yams are probably poor hosts or non-hosts to root-knot nematodes. Nevertheless, nematicide applications may be beneficial to these and other long-term crops, especially papaya. Up-to-date information on nematicides used on these crops is not available at Central Farm. For papayas and pineapples, it could probably be obtained from Hawaii. Current labels for all the nematicides listed in Appendix III should be obtained from the manufacturers or other sources.

The use of regular insecticide sprays to control unspecified pests should be discouraged. If such programs are initiated and a clean crop is the result, it may not be determined if the insecticide was responsible or if serious pests were simply not present. The development of resistant insects and outbreaks of secondary pests may also be encouraged. During the dry season, outbreaks of leaf miners, spider mites, whiteflies, and other secondary pests are especially threatening. For example, many of the broad-spectrum phosphate insecticides have some acaracidal activity, e.g., aziniphos-methyl, diazinon, malathion, methamidophos, methyl parathion, and oxydemethon-methyl. Usually they are sprayed for the control of insect pests, not mites. Some of the plant-feeding mites have

developed resistance to phosphate acaracides. Yet many predacious mites and other mite preditors have not. Thus frequent long-term use of these chemicals may lead to serious problems with mites in vulnerable crops such as papaya, okra, squash, and tomato. Insecticides should be introduced to the program as they are needed to control specific insect pests. This will require fairly intensive scouting, particularly during the initial phases of the program. Later, as experience is gained, insecticide programs may be adopted to control the more widespread and omnipresent insect pests.

Some exceptions to this recommendation might be made in the case of insect vectors of plant diseases. In many cases, even excellent suppression of insect vectors will not control the spread of virus diseases in the field. However some advantage may be gained by protecting young crops. An efficient means of doing this would be to apply a systemic insecticide/nematicide to the soil at planting or transplanting time. Beans, corn, cucurbits, peppers, tomatoes, and other crops with virus problems may respond favorably to such treatments.

D. Pesticide Application and Use

Most farmers in Belize are familiar with compressed air knapsack sprayers such as those manufactured by Cooper Pegler (CP-3) and Solo. But many have difficulties with dosage and calibration, and some are unaware of or oblivious to even elementary safety precautions. If agrichemicals recommended by project staff are to be applied safely and correctly, cooperating farmers will have to be educated. Training manuals for pesticide applicators are available from many land grant colleges in the U. S. Perhaps one of these would be fairly well-suited for training farmers who work in the project.

If training is ignored, errors in application may result in poor-quality produce or residue problems. The latter is especially likely if free chemicals are provided, as the project plan apparently calls for. Product abuse would be less likely if farmers shared in chemical costs to some extent. Education efforts would be facilitated if all farmers had the same spraying equipment, e.g., all CP-3 or Solo sprayers. Maintenance and parts problems would also be reduced. The provision of such sprayers to farmers with demonstration plots this year (at a subsidized cost of $100 - 150 / unit) would be a worthwhile investment. Whenever possible, liquid pesticide formulations should be recommended over wettable powders (WP), as they are more easily mixed with water and more accurately measured. Because WP formulations are markedly cheaper and more available in some cases (e.g., carbaryl and mancozeb) proper mixing procedures will have to be taught.

After the first year, project participants will probably be encouraged to increase their output of selected vegetables and fruits. Acreages will be increased and farmers will find it increasingly difficult to maintain spray programs with manual sprayers. The use of motorized mist blowers (MMB) would be the next logical jump in spray technology. MMB's also offer some advantages over knapsack sprayers in efficiency of pest control. The fine droplet size produced by MMB should result in better spray distribution on upper and lower leaf surfaces. Improved coverage will result in better control of many diseases and some insects which congregate on the abaxial surface. On the negative side, applications should not be made during windy conditions. Spray coverage is adversely affected by wind and spray drift poses an added hazard to the operator.

SPECIFIC RECOMMENDATIONS FOR 1985-86

A. The Nursery

Because of the advantages of early entry into the U.S. winter vegetable market, seedbeds may be established in October and November. This is early by traditional Belizean standards. The seedlings will be germinating and growing during a period of relatively cool temperatures and occasional rains. These conditions are quite favorable to many damping-off and foliar blight diseases. The potential for damping-off would be much reduced by soil fumigation of the seedbeds and/or potting soil. Methyl bromide is recommended because it is an extremely broad spectrum biocide (eliminating fungi, nematodes, soil insects, weed seed, etc.) and a highly volatile chemical (giving it good mobility in the soil). Fumigation will not only control damping-off pathogens, but also reduce the chances of spreading soil-borne pests such as Phytophthora, Corticium, Meloidogyne, and Cyperus spp. from the nursery area into the fields of cooperating farmers.

It is a very risky proposition to base the initial testing phase of the project on the production of one main nursery. Since this is the case, everything possible must be done to insure the production of vigorous, healthy seedlings. Some of these measures, including soil fumigation, may not have been necessary if individual nurseries had been located on each farm. The erection of a plastic roof over the seedbed would aid considerably in the control of most seeding diseases, including damping off. A roof made of plastic sheeting was placed over the tomato nursery at Baker's Ranch and immediately aided in the control of leaf diseases such as early blight and Rhizoctonia leaf blight. But even with this type of protection, regular fungicide sprays will be needed. Tomato and pepper seedlings should be sprayed every 4 - 5 days with chlorothalonil or a mixture of mancozeb plus benomyl. If leaf spot control is inadequate, bacterial spot disease may be present (see Appendix II). The purpose of roofing is to reduce the period of leaf wetting which is conducive to disease development. Seedlings under roof will have to be watered. This should be done around mid-day (if shading is available) in order to decrease the overall time of leaf wetting. Shading may not be necessary or even desirable during the October to January period. If it is not employed, watering early in the morning is recommended.

The nursery area should be fenced in to exclude loose cattle, pigs, and dogs. Broadleaf weeds and nearby plantings of vegetables and ornamentals should be eliminated to reduce the possibility of virus spread. The incorporation of carbofuran into the seedbeds or potting soil prior to planting is also recommended. To be on the safe side, 100 percent redundancy is suggested. Growing twice as many seedlings as are actually needed by the project should help to guarantee a sufficient supply if unforeseen problems arise. The extras should be grown in a second seedbed, planted approximately one week after the first one. Thus a steady supply of properly sized seedlings will be available over a longer period of time, if transplanting is delayed for some reason. If necessary, tomato transplants could be retarded and made stouter by the application of the growth regulator diaminocide (Uniroyl Chemical Co.). Sprays of copper fungicides also may be used to suppress the growth of tomato seedlings in nurseries.

B. Achieving a Good Stand

Difficulties may be encountered in achieving uniform plant stands for direct-seeded crops. Early-planted crops are particularly vulnerable because late season rains may still be encountered in October and November. Wet soils and relatively cool temperatures are adverse to seed germination and favorable to damping-off diseases. Early land preparation, which allows time for plant residues to decompose, suppresses some damping-off fungi. Good land preparation, as described in the section on weeds, will help to control cutworms, grubs, and other soil insects. Fungicide seed treatments are beneficial, especially when soil conditions are adverse to germination and emergence. If snap beans and sweet corn are selected as export crops, a bulk seed treater may be a worthwhile investment. Thiram, captan, benomyl, and PCNB are the most widely used seed treatment fungicides.

C. Pesticide Procurement

Some foreign-aid projects purchase pesticides directly from overseas manufacturers, thus by-passing Belizean importers or distributors. The main advantages are reduced cost and timely receipt of the product. The major disadvantage is the weakening or lack of development of in-country supply and distribution networks. When the project ends, farmers may be hard-pressed to find chemicals and supplies previously obtained by the project. Whenever possible, needed pesticides should be ordered through Belizean suppliers. To insure that specific chemicals are available in sufficient quantities, inquiries should be made and retainers paid, if necessary.

D. Ongoing Pest Management Assistance

The BCAC project will be introducing new elements into the Belize agricultural ecosystem. Among these are new crops or larger acreages of traditional crops; intensive use of agrichemicals including fertilizers; and new irrigation systems. All these introductions will have pest management ramifications. Pest problems will arise which may be unique to this area and not amenible to standard control programs or products which are used in the U. S. For this reason, continuing assistance in the area of pest management may be necessary for the ultimate success of the project. It will be particularly important during the 1985-87 start-up phase as new crops and new varieties are being introduced and evaluated. Pest management expertise is available in Belize. Jose Novelo, BABCO Manager, is a trained entomologist. Reis Williford is a Peace Corps Plant Pathologist who is working at the BSI research laboratories in Libertad. Previous conversations indicate that he would be interested in assisting the project on a part-time basis. Finally, Dr. Robert Black is a mycologist and plant pathologist who heads the Plant Protection Section at Central Farm. He has indicated a willingness to help if a major disease problem is encountered. However, some assistance with transport or fuel might be necessary.

E. End

I would like to extend my best wishes for the project and to the personnel in BABCO and Chemonics with whom I have become acquainted. It is my hope that this report will, in some small way, contribute to its success.

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APPENDIX I: PLANT PATHOGEN / INSECT LISTS

BEANS (*Phaseolus vulgaris*)

Alternaria sp.	fungus	*Alternaria* leaf spot
Cercospora sp.	fungus	*Cercospora* leaf spot
+*Collectotrichum lindemuthianum*	fungus	Anthracnose
+*Corticium microsclerotia* (*Rhizoctonia microsclerotia*)	fungus	Web blight
+*Corticium rolfsii* (*Sclerotium rolfsii*)	fungus	Southern blight
Erysiphe polygoni	fungus	Powdery mildew
Fusarium solani	fungus	*Fusarium* root rot
Isariopsis griseola	fungus	Angular leaf spot
Macrophomina phaseolina	fungus	Ashy stem blight
Meloidogyne spp.	nematode	Root-knot nematode
Pseudomonas phaseolicola	bacteria	Halo blight
Rhizoctonia solani	fungus	Damping-off
+*Uromyces phaseoli* var. *typica*	fungus	Rust
Xanthomonas phaseoli	bacteria	Common blight
+Bean mosaic virus(es)	virus	

Bean Insect Pests

Acanthoscelides obtectus	Coleoptera: Bruchidae	storage pest
Acallia lingula	Homoptera: Cicadellidae	foliage
Apion aduncirostre	Coleoptera: Cucurlionidae	foliage
Balclutha sp.	Homoptera: Cicadellidae	foliage
+*Bemisia tabaci*	Homoptera: Aleyrodidae	foliage
Catagonia miniaticens	Homoptera:	foliage
Cedusa sp.	Homoptera: Derbidae	foliage
+*Cerotoma ruficornis*	Coleoptera: Chrysomelidae	defoliates
Colaspis lebasi	Coleoptera: Chrysomelidae	defoliates
Gonoderus sp.	Coleoptera: Elateridae	defoliates
Dasydactylus sp.	Coleoptera: Languriidae	defoliates
+*Diabrotica* spp. (3)	Coleoptera: Chrysomelidae	defoliates
Disonycha glabrata	Coleoptera: Chrysomelidae	defoliates
+*Empoasca kraemeri*	Homoptera: Cicadellidae	foliage
Epilachna borealis	Coleoptera: Coccinellidae	defoliates

Bean Insects...continued

Erythrogonia laudata	Homoptera: Cicadellidae	foliage
Enschistus spp. (2)	Hemiptera: Pentatomidae	—
Gypona sp.	Homoptera: Cicadellidae	foliage
Halticus citri	Hemiptera: Miridae	foliage
+Heliothus virescens	Lepidoptera: Noctuidae	pod borer
Homophoeta acquinoctialis	Coleoptera: Chrysomelidae	defoliates
Hortensia similis	Homoptera: Cicadellidae	foliage
Jadera aeola	Hemiptera: Rhopalidae	—
Lamprosema indicata	Lepidoptera: Pyralidae	leaf tyer
Linogeraeus lineolus	Coleoptera: Curculionidae	—
Oncoreltus sandarachatus	Hemiptera: [illegible]eidae	—
Phyllotreta guatemalensis	Coleoptera: Chrysomelidae	defoliates
Pseudoplusia includens	Lepidoptera: Noctuidae	defoliates
Sitona sp.	Coleoptera: Curculionidae	defoliates
Spissistilus festinus	Homoptera: Membracidae	—
Systena taeniata	Coleoptera: Chrysomelidae	defoliates
Urbanus proteus	Lepidoptera: Hesperiidae	leaf roller, defol.
+Vaginulus plebeius	Pulmonata: Veronicellidae	Slug
Zabrotes subfasciatus	Coleoptera: Bruchidae	storage pest

CHAYOTE, CHO-CHO (Sechium edule)

+Cercospora sp.	fungus	leaf spot
Corynespora sp.	fungus	leaf spot
Oidium sp.	fungus	powdery mildew

Cho-cho Insect Pests

Diaphania nitidalis	Lepidoptera: Pyralidae	bores fruit

CORN (Zea mays)

+Cochliobolus heterostrophus (Helminthosporium maydis)	fungus	Southern corn leaf blight
Curvularia spp.	fungus	Curvularia leaf spot
+Puccinia polysora	fungus	Southern rust
Sclerospora sorghi?	fungus	Downy mildew
Ustilago maydis	fungus	Common smut

Corn diseases...continued

Corn stunt mycoplasm	mycoplasm	corn stunt disease
Mosaic virus(es)	virus	
Unknown bacterium	bacteria	whorl rot (young plants)

Corn Insect Pests

Acalymma sp.	Coleoptera: Chrysomelidae	defoliates
Acrosternum marginata	Hemiptera: Pentatomidae	--
+*Aeneolamia postica jugata*	Homoptera: Cercopidae	roots, stem, foliage
Anasa scorbutica	Hemiptera: Coreidae	--
Aphthona diversa	Coleoptera: Chrysomelidae	--
Apion aduncirostre	Coleoptera: Curculionidae	--
Atta cephalotes	Hymenoptera: Formicidae	leaf cutting (ants)
Balclutha sp.	Homoptera: Cicadellidae	foliage
Baldulus maidus	Homoptera: Cicadellidae	foliage
Biolleyana mictifrons	Homoptera: Nogodinidae	foliage
Blissus sp.	Hemiptera: Lygaeidae	--
Cardioscarta mulchella	Homoptera: Cicadellidae	foliage
Carpophilus mutilatus	Coleoptera: Nitidulidae	ears
Catagonia miniaticeps	Homoptera: Cicadellidae	foliage
Cathartus quadricollus	Coleoptera: Cucujidae	grains
Ceraspis nilatei	Coleoptera: Scarabaeidae	--
Ceratocapsus punctulatus	Hemiptera: Miridae	--
Ceratoma ruficornis	Coleoptera: Chrysomelidae	defoliates
Chaetonema separata	Coleoptera: Chrysomelidae	defoliates
Chaetopsis sp.	Diptera: Otitidae	stalk borer
Chalepus bellulus	Coleoptera: Chrysomelidae	leaf miner?
Cobubathra sp.	Lepidoptera: Noctuidae	silk, grains
Colaspis sp.	Coleoptera: Chrysomelidae	--
Collaria oleosa	Hemiptera: Miridae	--
Conocephalus sp.	Orthoptera: Tettigoniidae	foliage
Conoderus sp.	Coleoptera: Elateridae	defoliates
Cossonus sp.	Coleoptera: Curculionidae	herbivore?
Crepidodera insularis	Coleoptera: Chrysomelidae	--
+*Diabrotica* spp. (5)	Coleoptera: Chrysomelidae	defoliates
+*Diatraea* spp. (3)	Lepidoptera: Pyralidae	stalk borer

Corn Insects...continued

Dichroplus sp.	Orthoptera: Acrididae	foliage
Diedrocephala sanguinolenta	Homoptera: Cicadellidae	foliage
Diphaulaca sulica	Coleoptera: Chrysomelidae	defoliates
Disonycha glabrata	Coleoptera: Chrysomelidae	defoliates
Draeculacephala sp. mollipes	Homoptera: Cicadellidae	--
Dysdercus sp.	Hemiptera: Pyrrhocoridae	--
Edessa spp. (2)	Hemiptera: Pentatomidae	grain
Empoasca sp.	Homoptera: Cicadellidae	foliage
Epicauta viticollus	Coleoptera: Meloidae	---
Epilachna borealis	Coleoptera: Coccinellidae	defoliates
Epitrix sp.	Coleoptera: Coccinellidae	--
Erythrogonia spp. (2)	Homoptera: Cicadellidae	foliage
Eumecosomyia nubila	Diptera: Otitidae	stalk borer
Enschistus spp. (2)	Hemiptera: Pentatomidae	--
Geraeus senilis	Coleoptera: Curculionidae	--
Gyrocnemis quadrisignatus	Hemiptera: Thyreocoridae	--
Halticus citri	Hemiptera: Miridae	foliage
+Heliothis zea	Lepidoptera: Noctuidae	ears
Hermaeophaga sp.	Coleoptera: Chrysomelidae	--
Homophoeta aequinoctialis	Coleoptera: Chrysomelidae	defoliates
Homotyphus sp.	Coleoptera: Chrysomelidae	herbivor
Hortensia similis	Homoptera: Cicadellidae	foliage
Hypselonotus cocinnus	Hemiptera: Coreidae	--
Hypselonotus linearis	Hemiptera; Coreidae	--
Ischnodemus sallei	Hemiptera: Lygaeidae	--
Largus varians	Hemiptera: Largidae	--
Leptoglossus stigma	Hemiptera: Coreidae	--
Longitharsus spp. (2)	Coleoptera: Chrysomelidae	--
Lophoampa annulosa	Lepidoptera: Aretiidae	ear
Maseorhynchus hondurensis	Coleoptera: Curculionidae	defoliates (seedlings)
Microctenochira ferranti	Coleoptera: Chrysomelidae	--
Mormidea pictiventris	Hemiptera: Pentatomidae	sucks grains
Myochrous spp. (2)	Coleoptera: Chrysomelidae	defoliates
Nodonota apacicollis	Coleoptera: Chrysomelidae	defoliates
Oedionychus decemguttatus	Coleoptera: Chrysomelidae	--

Corn Insects...continued

Oliarus sp.	Homoptera: Cixiidae	foliage
Peregrinus maidus	Homoptera: Delphacidae	foliage
Phera obtusifrons	Homoptera: Cicadellidae	--
Phyllotreta guatemalensis	Coleoptera: Chrysomelidae	--
Planicephalus flaircosta	Homoptera: Cicadellidae	foliage
Platytylellus latipennis	Hemiptera: Miridae	--
Prepodes lunarius	Coleoptera: Curculionidae	--
Prosapia spp. (2)	Homoptera: Cercoptidae	foliage
Pseudomopsis similis	Coleoptera Curculionidae	--
Reuteroscopus ornatus	Hemiptera: Miridae	--
Rhinotmetus modestus	Coleoptera: Chrysomelidae	--
Rhopalosiphum maidus	Homoptera: Aphididae	foliage
Sitona sp.	Coleoptera: Curculionidae	defoliates
Sitophilus zeamais	Coleoptera: Curculionidae	grain
Sogatella meridiana	Homoptera: Delphacidae	--
+Spodoptera frugiperda	Lepidoptera: Noctuidae	defoliates
Strabala acuminata	Coleoptera: Chrysomelidae	--
Systena taeniata	Coleoptera: Chrysomelidae	defoliates
Tanymecus sp.	Coleoptera: Curculionidae	--
Taosa herbida	Homoptera: Dictyopharidae	foliage
Teleonemia scrupulosa	Hemiptera: Tingidae	--
Typophorus paradoxa	Coleoptera: Chrysomelidae	defoliates
Zelus spp.	Hemiptera: Reduviidae	preditor
Zicca recurva	Hemiptera: Coreidae	--

CUCURBITS (Citrullus vulgaris, Cucumis spp., Cucurbita spp.)

Choanephora cucurbitarum	fungus	Blossom blight
Corynespora cassiicola	fungus	Target spot
+Didymella bryoniae (Mycosphaerella melonis)	fungus	Gummy stem blight
+Erysiphae sp.	fungus	Powdery mildew
Fusarium spp.	fungi	Fusarium wilt
Glomerella cingulata (Collectotrichum lagenarium)	fungus	Anthracnose

Cucurbit diseases...continued

+*Meloidogyne* spp.	nematode	Root-knot nematode
Pseudomonas lachrymans	bacteria	Angular leaf spot
+*Pseudoperonospora cubensis*	fungus	Downy mildew
+Watermelon mosaic virus	virus	
Unidentified virus diseases	virus(es)	
A physiological disease	none	Blossom end rot

Cucurbit Insect Pests

Acalymma blomorum	Coleoptera: Chrysomelidae	defoliates
A. vittatum	Coleoptera: Chrysomelidae	defoliates
Agallia linguula	Homoptera: Cicadellidae	foliage
Anasa scorbutica	Hemiptera: Coreidae	--
+*Aphis gossypii*	Homoptera: Aphididae	foliage
Bothrophorella nigra	Hemiptera: Miridae	--
Cerotoma ruficornis	Coleoptera: Chrysomelidae	defoliates
+*Diaphania hyalinata*	Lepidoptera: Pyralididae	fruit borer
+*D. nitidalis*	Lepidoptera: Pyralididae	fruits, flowers, stems
+*Diabrotica balteata*	Coleoptera: Chrysomelidae	leaves, flowers, stems
D. lepida	Coleoptera: Chrysomelidae	as above?
Epilachna borealis	Coleoptera: Coccinellidae	defoliates
Erithrogonia jucunda	Homoptera: Cicadellidae	foliage
E. laudata	Homoptera: Cicadellidae	foliage
Halticus citri	Hemiptera: Miridae	--
Homophoeta aequinoctialis	Coleoptera: Chrysomelidae	defoliates
Myochrous tibialis	Coleoptera: Chrysomelidae	defoliates
Notograma stigma	Diptera: Otitidae	stem borer
wireworms	Coleoptera: Elateridae	fruit borer (cantaloupe)
+ ?	Coleoptera?	stem borer (squash)

OKRA (*Hibiscus esculentus*)

+*Cercospora abelmoschii*	fungus	*Cercospora* leaf mold
+*Meloidogyne* spp.	nematode	Root-knot nematode
Unidentified virus disease(s)	virus	

Okra Insect Pests

+*Aphis gossypii*	Homoptera: Aphididae	foliage, vines
Colaspis hypochlora	Coleoptera: Chrysomelidae	—
Diabrotica balteata	Coleoptera: Chrysomelidae	defoliates
+*Dysdercus* sp.	Hemiptera: Pyrrhocoridae	—
Enschistus bifibulus	Hemiptera: Pentatomidae	—
Oedionychus clypeatus	Coleoptera: Chrysomelidae	—
Oncometopia clarior	Homoptera: Cicadellidae	foliage
Pseudophera contraria	Homoptera: Cicadellidae	foliage
P. divergens	Homoptera: Cicadellidae	foliage

PAPAYA (*Carica papaya*)

+*Collectotrichum papayae*	fungus	Anthracnose
Fusarium spp.	fungi	Root rot
+*Meloidogyne* spp.	nematode	Root-knot nematode
+*Phytophthora* sp.	fungus	*Phytophthora* root rot
+Bunchy top / dieback	MLO / virus?	

Papaya Insect Pests

Aconophora pallescens	Homoptera: Membracidae	foliage, shoots
+*Paracoccus* spp.	Homoptera: Pseudococcidae	stem, foliage, fruit
+*Toxotrypana curvicauda*	Diptera: Tephritidae	fruit fly
aphids (*Aphis gossypii*?)	Homoptera: Aphididae	foliage, stem
leafhoppers	Homoptera: Cicadellidae	foliage
+spider mites	Acarida: Tetranychidae	foliage

PEPPERS (*Capsicum* spp.)

Cercospora capsici	fungus	Frog-eye leaf spot
Collectotrichum nigrum	fungus	Anthracnose (fruit rot)
Corticium rolfsii (*Sclerotium rolfsii*)	fungus	Southern blight
Macrophomina sp.	fungus	Stem blight
+*Meloidogyne* spp.	nematodes	Root-knot nematode
Phomopsis sp.	fungus	Fruit rot
+*Phytophthora* sp.	fungus	Root rot, stem canker
+*Pseudomonas solanacearum*	bacteria	Bacterial wilt

Pepper Diseases...continued

+Xanthomonas vesicatoria	bacteria	Bacterial spot
+Mosaics and other virus(es)	virus	

Pepper Insect Pests

Agallia liguula	Homoptera: Cicadellidae	foliage
Anasa scorbutica	Hemiptera: Coreidae	foliage
+Anthonomus eugenii	Coleoptera: Cuculionidae	fruits, buds
Ceratoma ruficornis	Coleoptera: Chrysomelidae	defoliates
+Diabrotica spp. (2)	Coleoptera: Chrysomelidae	defoliates
Dysdercus capitatus	Hemiptera: Pyrrhocoridae	--
Epilachna borealis	Coleoptera: Coccinellidae	defoliates
Epitrix sp.	Coleoptera: Chrysomelidae	defoliates
Erythrogonia spp. (3)	Homoptera: Cicadellidae	foliage
Hortensia similis	Homoptera: Cicadellidae	foliage
+Myzus persicae	Homoptera: Aphididae	foliage
Oncometopia charior	Homoptera: Cicadellidae	foliage
Orthezia insiginis	Homoptera: Ortheziidae	stems
Platytylellus latipennis	Hemiptera: Miridae	--
Pseudophera divergens	Homoptera: Cicadellidae	stem

PINEAPPLE (Ananas comosus)

+Phytophthora sp.	fungus	Phytophthora root rot
various fungi		Fruitlet core rot
+alkaline soils	none	yellowing

Pineapple Insect Pests

Dysmicoccus brevipes(?)	Homoptera: Pseudococcidae	roots, fruit
Mormidae pictiventris	Hemiptera: Pentatomidae	--
vertebrates (birds, possoms, etc.)		fruits

TOMATO (Lycopersion esculentum)

+Alternaria solani	fungus	Early blight, stem canker
Cercospora sp.	fungus	Leaf spot
+Corticium rolfsii (Sclerotium rolfsii)	fungus	Southern blight

Tomato diseases...continued

Corynespora cassiicola	fungus	Target (leaf) spot
Fulvia fulva (Cladosporium fulva)	fungus	Leaf mold
Fusarium oxysporum f.sp. lycopersici	fungus	Fusarium wilt
Macrophomina sp.	fungus	Stem rot
+Meloidogyne spp.	nematode	Root-knot nematode
Phoma (or Phyllosticta?) sp.	fungus	Leaf spot
+Pseudomonas solanacearum	bacteria	Bacterial wilt
+Thanatephorus cucumeris (Rhizoctonia solani)	fungus	Rhizoctonia leaf blight
+Xanthomonas vesicatoria	bacteria	Bacterial spot
+Mosaic and other virus(es)	virus	
Physiological disease	none	Blossom end rot

Tomato Insect Pests

Aclaymma vittatum	Coleoptera: Chrysomelidae	defoliates
+Diabrotica balteata	Coleoptera: Chrysomelidae	defoliates
Epicanta viticollis	Coleoptera: Meloidae	--
Epitrix sp.	Coleoptera: Chrysomelidae	--
+Enschistus bifibulus	Hemiptera: Pentitomidae	sucks fruit
+Faustinus ovatipennus	Coleoptera: Curculionidae	stem borer
Halticus citri	Hemiptera: Myridae	foliage
Heliothus virescens	Lepidoptera: Noctuidae	fruit borer
H. zea	Lepidoptera: Noctuidae	fruit borer
Herpetogramma phaeopteralis	Lepidoptera: Pyralidae	defoliates
Leptoglossus gonagra	Hemiptera: Coreidae	sucks fruit
+Phthia picta	Hemiptera: Coreidae	sucks fruit
Phyrdenus divergens	Coleoptera: Curculionidae	--
+Pseudoplusia includens	Lepidoptera: Noctuidae	fruit borer, defol.
Spodoptera dolichos	Lepidoptera: Noctuidae	fruit borer
S. eridania	Lepidoptera: Noctuidae	defoliates
S. latifascia	Lepidoptera: Noctuidae	defoliates
S. ornithogalli	Lepidoptera: Noctuidae	fruit borer
Zicca taeniola	Hemiptera: Coreidae	--

YAMS, COCO (*Colocasia esculenta*) (*Xanthosoma indica*?)

+*Xanthomonas campestris* var. *aracearum*? (*X. diffenbachia*)	bacteria	Bacterial leaf spot
+unknown pathogen(s)	fungi?	Corm rot

Coco Yam Insect Pests

Lema reluceng	Coleoptera: Chrysomelidae	—
Oedionychus decemgutatus	Coleoptera: Chrysomelidae	—
Platytylellus latipennis	Hemiptera: Miridae	—
Typophorus paradoxus	Coleoptera: Chrysomelidae	defoliates

APPENDIX II: DESCRIPTIONS OF SOME COMMON PESTS

This appendix includes excerpts from the extension bulletin on cucurbits (Mertely, 1986) and several fact sheets describing serious plant diseases in Belize.

PICKLEWORM (Diaphania nitidalis) & MELONWORM (Diaphania hyalinata)

Pickleworms and melonworms are green to cream-colored caterpillars which bore into cucurbit fruits. They are 1/2 - 3/4 inch long and have a brownish head. The adults are small moths with a wingspan of about 1 1/4 inches and prominent brush-like hairs at the tip of the abdomen.

Hosts. Most vine crops are attacked by both pickleworms and melonworms. Muskmelons, cucumbers, and squash are preferred hosts and may be seriously damaged by either insect. Frequently both insects are present in the same field. Pumpkins are attacked by melonworms, but not pickleworms. Watermelons are rarely affected by either pest.

Life cycle. Economic losses are caused by the caterpillars, not the adult moths. During the day, the moths hide under leaves and around flowers of cucurbit plants. Eggs are deposited by female moths during the night. The eggs hatch into tiny caterpillars which feed on buds, blossoms, and leaves. Fruit boring occurs later, after the caterpillars have grown a little larger. When squash is attacked by pickleworms, leaf stalks, shoots, and stems are also bored. After feeding for about two weeks, the worms pupate and eventually change into adult moths. This entire life cycle takes 3-5 weeks to complete.

Control. Adult moths are usually noticed in the field after the plants have begun to flower. When disturbed, they fly short distances close to the ground and quickly find another vine to hide under. Worms may also be found in the flowers and buds. When these signs are observed, insecticide sprays should begin. If honeybees are present, it is best to spray later in the day, after they have returned to the hive. Sevin, Tamaron, or Lannate may be used to control both pickleworms and melonworms. Malathion is labeled for use against pickleworms only, while Dipel is effective against melonworms, but not pickleworms. The entire plant, including the vine tips and flowers, must be covered by the spray. Several applications may be necessary for good control.

Normal crop sanitation practices will also help to control these pests. During the harvest period, wormy fruits should be picked and destroyed or fed to livestock. After the last harvest, crop debris (especially fruits and vines) should be gathered up and burned, burried, or used to make compost. Harrowing and deep plowing of production fields is an alternative in mechanized operations.

CUCUMBER BEETLES (Diabrotica spp.)

Cucumber beetles (Diabroticas) are small hard-bodied insects less than 1/4 inch in length. Their hard outer wings are crossed by alternating bands of color, giving their bodies a striped appearance. The colors are usually green and yellow or brown and yellow.

Hosts. Diabroticas are general feeders which attack a wide variety of crops. Field crops such as beans, corn, and rice are hosts. Tomato, pepper, cabbage, and other vegetables are also attacked. Among the vine crops, these beetles prefer to feed on cucumber, but muskmelon, pumpkin, squash, and watermelon are also damaged.

Life cycle and damage. Like all beetles, Diabroticas are chewing insects. Both the immature larvae and the adult beetles damage cucurbit crops. The larvae are small light colored worms which live in the soil and feed on the roots and underground parts of the stem. After feeding for 2-6 weeks, they pupate and emerge from the soil as adult beetles. The adults feed on flowers, leaves, and stems. The most serious damage occurs when the beetles feed on seedlings or flowers of older plants. Feeding on seedlings results in damage to the leaves and superficial scaring or girdling of the stem.

Control. Cucurbits are most sensitive to damage during the seedling stage. It is very important to maintain control of the adult beetles for the first 3-4 weeks after planting. After this period, cucumber beetles may still cause injury by chewing on the leaves and flowers. However, older plants can endure much damage of this type and still produce a good crop. Occasionally large numbers of beetles will infest older crops of cucumbers and muskmelons. Then it may be necessary to spray.

Cucumber beetles are sometimes difficult to control by chemical sprays. Local farmers report that Lannate does not work as well as in the past, possibly because the insect has developed resistance to this chemical. Other insecticides which are recommended for the control of adult Diabroticas are Sevin, Diazinon, Dipterex, Gusathion, and Methoxychlor.

Root damage by the larvae is not observed very often in local cucurbit crops. More damage might be expected if cucurbits immediately follow corn, beans, or other hosts in a crop rotation plan. The larvae can be controlled by soil applications of granular insecticides such as carbofuran (Furadan 15G, Curater 3G), Mocap, or Diazinon. Carbofuran is a systemic product which will also help protect the seedlings against adult feeding above ground. Good field preparation prior to planting helps to reduce the number of larvae in the soil.

APHIDS (*Aphis gossypii* and others)

Aphids are small soft-bodied insects which suck juices from soft parts of many different kinds of plants. They are about 1/16 inch long and often lack wings. Immature aphids (nymphs) and wingless adults move very slowly. On cucurbits, they are green to yellowish in color, and commonly occur in colonies on young shoots and the undersides of leaves.

Damage. Aphids are found on all species of vine crops. When present in large numbers, the infested leaves curl up and take on a light green color. Severe attacks result in stunting and yellowing of vines or entire plants. This is caused by the loss of sap and the injection of toxic saliva into the plants. Aphids also transmit virus diseases such as watermelon mosaic virus and cucumber mosaic virus. These diseases often cause more damage to cucurbit crops than the aphids themselves.

Life cycle. The melon aphid (Aphis gossypii) frequently infests cucurbit crops in Belize. Only females are found in this particular species. They may be winged or wingless. The adult females give birth to living young at the rate of one or two each day and have a life span of 2-3 weeks. This unusual type of reproduction results in very rapid increases in population. Severe infestations seem to build up almost overnight, and are especially common during the dry season.

Control. Aphids are sometimes found in low numbers which are relatively stable, not increasing rapidly over time. These populations are held in check by adverse weather and natural biological control. Preditors such as larvae of coccinellid beetles feed on aphids. Parasitic wasps and flies also help to keep aphid populations under control. In these situations, spraying with insecticides is not economic and may even lead to greater insect pest problems.

Severe infestations may require chemical control. Many insecticides are labeled for aphid control--Diazinon, Malathion, Guasthion, Lannate, Tamaron, and Metasystox-R. The first three are contact insecticides. They provide adequate control when care is taken to obtain good spray coverage. The second three are systemic insecticides which are better able to penetrate and kill aphids hidden on the undersides of leaves.

LEAF MINERS (Liriomyza spp.)

Leaf miners are the immature stages of various moths and flies. They burrow into leaves and feed on the inside, eating tissues between the two outer layers or skins of the leaf. On the outside, the eaten areas are white or clearish in color, and look like blotches or long winding tunnels.

Life cycle. Only one type of leaf miner (Liriomyza spp.) is known to attack vine crops in Belize. Damage usually occurs on watermelons, seldom on other vine crops. Tomatoes and beans are also hosts. The immature insect is a tiny maggot which forms tunnels inside the leaves of host crops. After feeding for a period of time, the maggot pupates and changes into an adult. The adult Liriomyza is a small fly.

Pest status. Information on leaf miners is not very abundant. This may be because leaf miners are usually thought of as minor pests which cause minimal or sporadic damage. Occasionally, leaf miners cause serious damage to a crop. These outbreaks often occur when insecticides are used excessively over long periods of time to control other insects in the crop. In the absence of insecticide sprays, leaf miners are partially controlled by other insects (preditors and parasites). But when these insects are killed by heavy or repeated use of insecticides, leaf miners can become a problem.

Control. Spraying for leaf miners is occasionally necessary, particularly on watermelons. Leaf miners are less important on other cucurbit crops. If watermelons are being sprayed for other pests and leaf miners suddenly become a problem, try switching to another chemical. If no insecticides have been used on the crop, begin spraying only when serious mining and damage to the leaves is observed. Diazinon, Dipterex, Gusathion, Nuvacron, Tamaron, and many other insecticides are labeled for leaf miners. In Belize, both Diazinon and Dipterex have been used effectively against leaf miners on tomatoes.

DOWNY MILDEW (*Pseudoperonospora cubensis*)

Downy mildew is a fungus disease which spots and blights the leaves of cucurbit crops. All types of cucurbits are susceptible, but in Belize watermelon and muskmelon crops are damaged most often. In mild attacks, only a few leaves are spotted and killed. Yields are reduced slightly, and the fruits may not be as sweet and flavorful as they should be. In severe attacks, large numbers of leaves are blighted and very few marketable fruit are produced.

Symptoms. Downy mildew infections first appear as light green or yellowish spots on the leaves. Older leaves near the base of the vine are usually spotted first. On muskmelon, cucumber, and squash, the spots are about 1/4 inch in size and square to angular in shape. On watermelons, the margins of the spots are less distinct and more rounded. As the spots become older, the yellow area eventually dies and becomes tan or brown in color. Badly spotted leaves dry up and turn brown.

Life cycle. The downy mildew fungus produces spores (tiny microscopic seeds) in the yellow areas on the underside of the leaf. The spores are blown by the wind to other leaves and plants. If the leaves are wet, the spores germinate and produce new spots in 4-7 days. The new spots produce new spores which infect still more leaves. Rains and high humidity favor this cycle of disease which may become an epidemic if not controlled.

Control. Downy mildew can be controlled by fungicides *if* a regular spray program is begun early. The first application should be made when the seedlings have developed their first true leaves (about 14 days after planting). Continue spraying at 5-7 day intervals through the harvest period (an 8-10 day interval will provide adequate control during hot dry weather). Common fungicides which can be used are mancozeb (Manzate 200, Dithane M-45), chlorothalonil (Bravo, Daconil), and Difoltan. In epidemic situations, expensive systemic fungicides such as Ridomil MZ-58-WP may be used to bring the disease under control.

Some varieties of cucumber and muskmelon are resistant or tolerant to downy mildew. In tests at Central Farm, all muskmelon varieties were damaged by the disease, but 'Magnum 45', 'Saticoy', and 'Perlita' still gave acceptable yields. 'Poinsette', 'Super Market', and 'Tropi-Cuke' proved to be the more resistant cucumber varieties.

GUMMY STEM BLIGHT
(*Mycosphaerella citrullina* = *Didymella bryoniae*)

Gummy stem blight is a fungus disease that attacks the leaves, stems, and fruits of cucurbit crops. Watermelons and muskmelons are most seriously damaged, although squash, cucumber, and pumpkin may also be attacked.

Symptoms. Stem cankers and leaf spots are the most damaging aspects of gummy stem blight disease. Cankers develop anywhere on the vine. They are dry brownish areas which split lengthwise and may be covered by dark gummy sap. The cankers enlarge slowly and gradually encircle or girdle the vine. When stems are attacked near ground level, the plants die prematurely and seldom produce marketable fruit. Leaf spots are more damaging on watermelons than other vine crops. The spots are dark brown to black in color and tend to occur near the margins of

the leaf. Faint circular or target-board patterns sometime can be seen in the dead central areas of the spots.

Life cycle. New crops are infected by gummy stem blight (GSB) in three ways: (1) diseased seeds, (2) spores, and (3) old crop debris. When diseased seeds are planted, some rot in the ground. Others emerge and quickly develop stem cankers in the area where the seed leaves are attached. The GSB fungus produces two types of spores. One type is produced on old plants or crop debris and is carried from field to field by the wind. The second type is produced in the leaf spots and stem cankers and is spread from plant to plant by splashing water. This second type of spore is responsible for the rapid spread of GSB within fields. The fungus also survives on plant debris (old decaying vines, fruits, etc.) from previous cucurbit crops. When cucurbits are grown continuously in the same field, new crops are soon infected by the fungus living in old crop debris.

Control. Gummy stem blight is controlled by a combination of good cultural practices and chemical sprays. Use treated seed from a reputable source, or extract seed from healthy fruits that show no sign of external spotting or rot. Destroy old crop debris by hand or by discing and deep plowing immediately after the harvest period. Practice crop rotation. After one or two crops, rotate to "new" land which has not been used to grow cucurbits for two or more years.

Watermelon and muskmelon crops must be sprayed regularly to protect against GSB, especially during cool rainy weather. The chemicals and spray program described for downy mildew will also control GSB. However, mancozeb is less effective than chlorothalonil or Difoltan against this disease. The systemic fungicide Benlate will control GSB, but not downy mildew.

WATERMELON MOSAIC VIRUS (WMV)

Watermelon mosaic is a virus disease which attacks plants in the cucurbit family. All types of cucurbits are susceptible to WMV, but watermelons are infected more often and more seriously than other vine crops. Yield losses of 50% and more have occurred in local watermelon fields.

Symptoms. Infected watermelon plants show a variety of symptoms. One of the most unusual is the tendency of infected vine tips to grow straight up into the air. From a distance, infected plants appear light green or slightly yellow in color. Closer up, the leaves are light green or mottled, narrowed, and occasionally crinkled or puckered. Fruit set is poor. Infected fruits are slightly rough or bumpy on the outside and ripen unevenly on the inside.

Life cycle. Watermelon mosaic virus (WMV) is not transmitted by seed and cannot survive in the soil. New crops are always free of the disease until they are invaded by aphids. Aphids are tiny sucking insects which transmit WMV. They pick up the virus while sucking sap from diseased plants and transmit WMV when they fly to healthy plants and feed again. The virus enters the plant at the feeding site, multiplies, and spreads systemically in the vine. Aphids feeding on the diseased vine will then spread the disease to other vines and plants in the field.

Control. Virus diseases are often very difficult to control. No chemicals are available which can cure a plant once it is infected by a virus. All commercial varieties of watermelon and squash are susceptible to WMV. Control measures must therefore be directed against the aphid transmitters. One method is to try to reduce the number of aphids which enter a young crop from outside the field. Older cucurbit crops have higher levels of disease and are usually infested by aphids. New watermelon crops should be planted as far away as possible from these older crops. Wild cucurbits and volunteer plants in and around the field must be destroyed prior to planting.

Spraying insecticides to kill aphids within a field is not very effective in controlling WMV. However, carbofuran may serve to delay infection and spread within a young crop. Carbofuran (Furadan, Curater) is a granular insecticide and nematicide which is applied to the soil at planting and is absorbed through the roots. Seedlings which have absorbed carbofuran repel aphids or kill them if feeding persists. The protection lasts from 4-6 weeks. Other insect pests are also controlled during this period.

ROOT-KNOT NEMATODES (*Meloidogyne* spp.)

Root-knot nematodes (RKN) are tiny worm-like animals that burrow into plant roots and feed from the inside. In reaction to this feeding, the roots swell up or form rounded galls in the areas where the nematodes are present. Infested plants grow poorly and may appear to be suffering from drought stress or nutrient deficiency. Lower yields of poorer quality fruit may be obtained.

Root-knot nematodes are commonly found in sandy Pine Ridge soils and loamy river valley soils. Fewer nematodes and less damage occurs on "heavy" soils with a large amount of clay. Most vine crops are extremely susceptible to this pest.

Life cycle. Mature female nematodes are embedded in roots and swollen with eggs. Each female produces up to 500 eggs which she lays in a jelly-like substance in or near the root. The eggs hatch to form larvae which move short distances through the soil in an attempt to find new roots. Movement is easier in sandy soils which have larger spaces between the soil particles. If suitable roots are found, the female larvae burrow in, feed, molt, and grow in size. Eventually they produce eggs. Under favorable conditions the entire life cycle (from egg to egg) is completed in 30-40 days.

Control. Some nematodes are readily controlled by crop rotation. They feed on a limited number of plants. When a farmer grows a crop they cannot feed on, they starve and gradually die out. Unfortunately, RKN feed on many different kinds of plants. *M. incognita* is one species of RKN that is very common in the tropics. It attacks over 700 species of plants including sugarcane, beans, tomato, potato, tobacco, carrot, cucumber, and many cereal crops. Rotation crops for root-knot infested soils are difficult to find. However, milpa land or land which has been in pasture usually have low numbers of RKN and would be suitable for growing one or two cycles of cucurbits.

Root-knot nematodes can be controlled by contact nematicides and fumigants. Contact nematicides come in granular form and are mixed with the soil (like fertilizer) at planting time. These chemicals may be

expensive and are often dangerous to handle. For maximum effectiveness, they should be thoroughly mixed with the soil. To save money, banded applications to the rows or spot applications to the hills are preferred to whole surface treatment. Furadan 15G and Mocap 10G are used in the States for nematode control on cucurbit crops.

Fumigants are liquid or gaseous products which are injected or drenched into the soil and sealed in with plastic tarps. They are expensive, extremely hazardous, and seldom economic given our present market conditions.

BLOSSOM END ROT & BLOSSOM BLIGHT

Blossom blights and rotting of the blossom end of the fruit are fairly common in cucurbit crops. They may be caused by disease organisms or unfavorable weather and soil conditions.

BLOSSOM END ROT

Blossom end rot (BER) commonly affects watermelon crops during the height of the dry season. Fruits are damaged on the blossom end where they become shriveled, blackened, and leathery. The remainder of the fruit is undamaged and may be perfectly good to eat.

The cause of blossom end rot is unknown. However, the condition rarely occurs during the rainy season. BER is associated with dry soil conditions and/or extreme changes in soil moisture. Maintaining good soil moisture during the dry season will help to minimize the problem.

Some varieties of watermelon may be more resistant to BER than others. Unfortunately, very little dry season testing of cucurbit varieties has been done in Belize.

BLOSSOM BLIGHT

Blossom blight (BB) is a pathogenic disease caused by the fungus *Choanephora cucurbitarum*. The disease is usually of minor importance. However, economic losses may occur during long rainy periods. Vine crops with large flowers (for example, squash and pumpkins) seem more susceptible to attack.

The blossom blight fungus is recognized by its unusual wisker-like growth on the flowers or rotting fruit. The "wiskers" or fungal hairs are erect, 1/4 - 1/2 inch long, and grayish in color except at the top, where a tiny black ball is present. Fungal spores are formed inside the black ball at the top of each fungal hair.

Symptoms. Diseased flowers become water soaked and quickly collapse into a mass of soft, wet, rotting material. The upper part of the fruit near the blossom may also be attacked and rotted.

Control. Any measures which improve air circulation or hasten drying of the plants will reduce losses to blossom blight. Avoid excessively thick planting, especially of bush squash, and maintain good control of weeds. Weekly applications of zineb, mancozeb, or Anthracol may be helpful.

LEAF DISEASES OF TOMATO (several pathogens)

There are at least eight different organisms which cause leaf diseases of tomatoes in Belize. One of these organisms is a bacterium; it is described in the bacterial spot fact sheet. The remaining seven pathogens are fungi. As a group, they are responsible for significant losses of production year after year in tomato plantings throughout Belize. Several of these fungi attack the fruits or stems. However, leaf damage accounts for most of the losses. When severe spotting and blighting of the leaves occurs, the plants are partially defoliated and the fruits are exposed to burning or bleaching by the sun. Damaged plants produce fewer, smaller fruit and tend to senesce and die prematurely.

Two of the more damaging fungi are Alternaria solani, which causes early blight, and Thanatephorus cucumeris, which causes Rhizoctonia leaf blight (RLB). RLB is a wet weather disease which severely blights tomato leaves whenever rains and cloudy conditions persist for more than two or three days. The fungus causes irregularly shaped brown areas on the leaves and may be visible on the lower leaf surface as a white mold growing on green tissues next to the brown areas. Early blight is also favored by rains and high humidity, although this disease may become severe during periods of normal rainfall or heavy dews. The early blight fungus attacks tomato stems and fruit, as well as the leaves. The leaf spots are brownish, roughly circular, and 1/4 - 1/2 inch in diameter. A target board or zonate pattern is usually seen in the spots. The stem cankers are dark gray, oval to elongate in shape, and also show a zonate pattern. Fruits are attacked on the fruit stalk or where the stalk joins the fruit.

Pathogens which attack tomato leaves usually survive between crops on old decaying residues from previous solanaceous crops. They may also persist on volunteer plants in the field and on broadleaf weeds--especially weeds in the Solanaceae family. To reduce the number of disease organisms which attack future crops, field sanitation and crop rotation should be practiced. Crop residues should be removed from the field and burned or composted as soon as possible after the last harvest. After growing one or more cycles of a solanaceous crop (i.e, tomatoes, potatoes, egg plant, or peppers) on a single piece of land, rotate to "new land" which has not been used to grow solanaceous crops for one or more years. Maintain good control of volunteer plants and broadleaf weeds in and around production fields.

Leaf diseases of tomato are routinely controlled by fungicide sprays. Broad-spectrum fungicides will control most foliar diseases, if a regular spray program is carried out. Fungicide sprays must begin in the seed bed, where crowding and high humidity contribute to the rapid spread of disease. (Seedlings should not be grown too close to producing tomato fields or on ground where tomatoes have been grown recently in the past). Spray seedlings every 4-6 days with a broad-spectrum fungicide such as mancozeb (Manzate 200, Dithane M-45), chlorothalonil (Bravo, Daconil), or captafol (Difolatan). After transplanting, and especially during wet weather, spray every 5-7 days. If wet weather persists, thiram (Thylate) is sometimes mixed with mancozeb to control Rhizoctonia diseases. During hot dry weather, 8-10 spray intervals are usually adequate. When using wettable powder fungicides, the addition of a spreader-sticker (such as Adherente or Triton) to the spray solution is strongly recommended.

Resistant or tolerant varieties of tomato are available. Most commercial varieties, for example, are resistant to Stemphylium leaf spot. The varieties 'Flora-dade', 'Calypso', 'Floramerica', and 'President' are all resistant or tolerant to Alternaria diseases. Unfortunately, no one variety is resistant to all of the leaf pathogens present in Belize. Fungicide sprays are still needed. Given the same spray program, however, resistant varieties usually produce fruit for a longer period of time than susceptible varieties. This is because their leaves are blighted and killed more slowly.

In a single test at Central Farm, several varieties appeared tolerant to Alternaria and/or Rhizoctonia diseases. Of these, only 'Flora-dade' and 'Tropic Boy' produced firm, durable fruits suitable for rough handling and long-term storage. 'Hope No. 1' fruits were somewhat softer, but also stored well.

J. M., July 1986

Bacterial Spot (*Xanthomonas vesicatoria*)

Bacterial spot is a bacterial disease which attacks the leaves and fruits of tomatoes and peppers. Sweet pepper crops are the most seriously affected. During rainy periods, irregular brown spots and watersoaked areas develop on the sweet pepper leaves. Older diseased leaves are easily broken off and fall to the ground. Infected plants grow slowly and give poor yields.

The bacteria grow and multiply in the diseased tissues and may be visible as a cream colored film on the spots. They are spread by splashing water or wind-driven rain. Bacterial spot spreads rapidly when damp or rainy conditions are present. When the diseased leaves begin to fall, the farmer becomes concerned and often starts to spray. Unfortunately, this action may be too late to control the disease, especially during rainy periods.

Chemical control must begin as soon as the spots appear. Sometimes even young plants in the seed bed must be sprayed. The best products for bacterial spot control are Agri-Mycin and Ultramycin. Both are mixtures of antibiotics and a copper fungicide. The second best choice is Cupravit Mix, a mixture of copper and maneb. Agri-Mycin, Ultramycin, and Cupravit Mix are not always available in Belize. Another option is to use two chemicals--a copper fungicide and mancozeb. Mancozeb, also known as Dithane M-45 or Manzate 200, is used at the rate of 2 lb/acre. The copper fungicide--either Kocide 101, Cupravit Forte, or basic copper sulfate--is used at 3 lb/acre. To each gallon of water add 1½ Bayer medidas+ (37 cc) of mancozeb and:

a. 2½ medidas of Kocide 101 ... or

b. 1¼ medidas of Cupravit Forte ... or

c. 1¼ medidas of basic copper sulfate.

Sprays must be applied every 4-5 days during rainy periods (if the disease is present). Always add a good spreader-sticker such as Adherente to the spray. The combination (of mancozeb, copper, and spreader-sticker) is also excellent for use on tomatoes. It controls bacterial spot and many other tomato diseases as well.

Bacterial spot can sometimes be avoided. After harvest, the bacteria survive in old plant debris. They also can be carried on seeds. If a field is infected with bacterial spot, crop rotation is advised. Do not plant tomatoes or peppers in the same field for two years. Be very careful not to locate seed beds in such areas. Also avoid using the seed for replanting.

At present, all commercial varieties of sweet peppers and tomatoes are susceptible to bacterial spot.

+Note: One Bayer medida or Bayer copa is equal to 25cc.

Bacterial Wilt (*Pseudomonas solanacearum*)

Bacterial wilt is one of the world's most serious diseases of solanaceous crops. It is caused by races 1 and 3 of the bacterium *Pseudomonas solanacearum*. (Race 2 attacks bananas and plantains, causing "Moko" disease).

In Belize, tomatoes, peppers and eggplants are often badly damaged by bacterial wilt. Young tomato plants wilt suddenly, without prior yellowing or stunting. The wilt is usually permanent and the plants die in a few days. Older tomato trees and most pepper varieties are more resistant and take longer to die. For these plants, the final permanent wilt may be preceeded by yellowing, stunting, root rot, and/or the development of adventitious roots on the lower stem.

P. solanacearum enters susceptible plants through the roots. Warm temperatures, high soil moisture, and root injury all increase the chances of infection. Root injuries occur when the roots are broken during transplant and cultivation operations. Certain nematodes and soil insects also damage the roots. After infection, the bacteria multiply rapidly in the roots and ooze out into the soil. They also invade the woody water-conducting tissues of the stem. Wilting occurs after vascular tissues in the roots and stem are damaged, discolored, and plugged up by the bacteria.

There are no effective chemicals for the control of bacterial wilt. Fumigation of the soil to eliminate wilt bacteria is not practical or economic in most cases. The best control is to avoid planting susceptible crops on contaminated land. New land (where tomatoes and peppers have not been grown before) is usually uncontaminated. If the disease is not present, avoid bringing contaminated soil or infected seedlings into the area. Contaminated soil is often carried on dirty farm machinery or impliments. Other disease control practices include:

1. Improving drainage or avoiding poorly-drained acid soils
2. Minimizing root damage during transplant and cultivation
3. Controlling nematodes, especially root-knot nematodes, if present
4. Removing diseased plants (including roots and surrounding soil)
5. Decontaminating land by growing nonhost crops and maintaining good control of broadleaf weeds for 1-2 years. Cabbage, squash, melons, cucumbers, corn, rice, soybeans, and pasture grasses are nonhost crops.

Plant breeders have been working for years to develop tomato varieties with high resistance to *P. solanacearum*. Resistant varieties (such as 'Kewalo' and 'BWN-21' from the University of Hawaii) are just becoming available. These varieties may or may not be resistant to the strains of *P. solanacearum* present in Belize. Also, they may or may not be adapted to our growing conditions. Testing is needed.

SOUTHERN BLIGHT (*Sclerotium rolfsii*)

Southern blight is a common and widespread disease caused by the fungus *Corticium rolfsii* (old name = *Sclerotium rolfsii*). A large variety of plants are attacked including vegetables, cereals, legumes, flowers, and weeds. Some of the more common hosts in Belize are tomatoes, peppers, peanuts, beans, and sweet potatoes. Usually less than 5% of a crop is killed by this disease.

C. rolfsii causes "damping-off" disease of seedlings and a collar rot (basal stem rot) of older plants. Seedlings are more susceptible than older plants of the same variety. Diseased seedlings die quickly. Older plants are attacked at the soil line where the pathogen is visible as a mat of white fungus (a mycelial mat) growing on the surface of the stem. *C. rolfsii* damages the plant by secreting enzymes and an acid which rot the stem cortex. As a result of this damage, the plant displays wilt-like symptoms such as drooping of the leaves, yellowing, and browning.

By the time the plant has died, its root system has been invaded and the fungus has formed sclerotia. Sclerotia are compact masses of fungus hyphae which can survive unfavorable environmental conditions. *C. rolfsii* forms its sclerotia on the surface of the mycelial mat. They are hard and brownish, and about the size and shape of cabbage seed. Usually the sclerotia remain at or near the soil surface, unless they are mixed with the soil during cultivation. In either case, sclerotia may survive for many years, even in the absence of a suitable host.

Most control measures for southern blight are directed against the sclerotia. These include: (1) crop sanitation, (2) deep plowing, and (3) chemical treatment of transplants. When a plant is killed by southern blight, it should be removed from the field along with some surrounding soil. This reduces the number of sclerotia that would otherwise remain in the field. Deep plowing after harvest buries many sclerotia and effectively puts them "out-of-range" of the next crop. Vegetable crops may be treated with Terraclor (75% PCNB) in the transplant water. Mix one pound of Terraclor with 25 gallons of water and apply one-half pint of the solution to the soil around each seedling. One application (done immediately after transplanting) should give sufficient control.

Some farmers claim that powdered limestone (marl) or burnt lime will prevent the disease. The lime is mixed with the soil around the stem. There may be some truth to this claim since the lime would neutralize the acid given off by the fungus. But one should be careful not to use too much burnt lime. It is a caustic substance which might burn the stem.

Several other factors increase losses to southern blight:

1. leaving crop debris on the soil surface
2. mulching the soil surface with partially decayed organic matter
3. heaping soil up around the stems of plants (during cultivation)
4. humid conditions at the soil surface

These factors should be avoided when growing crops susceptible to southern blight. Lower plant density and good control of weeds will reduce humidity at the soil surface.

ROOT-KNOT NEMATODES (*Meloidogyne* spp.)

The root-knot nematode, known scientifically as *Meloidogyne*, is the most damaging plant parasitic nematode in the tropics. Over 2000 different species of plants are affected. Most vegetable crops and some field crops are susceptible. Plantation crops such as coffee and banana, and certain weeds are also attacked. In Belize, serious damage has been observed on tomatoes, *Capsicum* peppers, and okra. Vine crops such as watermelon are also occasionally attacked.

Root-knot nematode damage is easily recognized. *Meloidogyne* spp. live in the soil and feed on roots and other underground plant parts such as tubers and corms. These parts must be dug up and examined to see if root-knot nematode is a problem. Diseased roots will have numerous bumps and swellings called galls. Galls caused by root-knot nematodes are roundish in shape and variable in size. Some may be less than 1/16 inch across; others may be over an inch in diameter. If the plants are attacked while young and high populations of nematodes are present, the major roots may swell up to several times their normal thickness.

Above ground, the symptoms are less specific. Infected plants grow slowly and look like they are suffering from drought or lack of fertilizer. The foliage may be pale green in color; sometimes the older leaves turn yellow. Infected plants often wilt in the afternoon, especially during dry weather. Heavily infected plants produce for a shorter period of time and may grow old and die prematurely. Yields are decreased, sometimes dramatically.

Root-knot nematodes are slender worm-like animals when they are young. They are too small to be seen by the naked eye. They move for short disdistances in the soil by swimming in the water between the soil particles. Over longer distances, they move with irrigation water, infested soil, and infected planting material. Only the young nematodes (larvae) enter the roots to feed. Once inside, the female larvae grow rapidly, changing from slender "worms" to swollen pear-shaped bodies filled with eggs. A single female may produce up to 500 eggs. These eggs hatch to produce more larvae. The entire life cycle—from eggs to adults to more eggs—takes approximately 30 days.

Root-knot nematode control is difficult. Once present in a piece of land, they are almost impossible to eliminate. Three practices effectively reduce root-knot populations to very low levels. These are soil fumigation, flooding, and fallowing. Unfortunately, treatment of the soil with chemical fumigants is very expensive and not cost effective for most crops. Flooding can be employed only under special circumstances (e.g., in rice producing areas). Fallowing is sometimes a practical alternative. To be effective, the soil must be turned over by disc or plow and then dried and kept free of weeds for several months. Our February to May dry period is an ideal time for fallowing.

Other control practices aim to reduce nematode numbers to an "ecomomic level". One cycle of a susceptible crop can then be grown without unacceptable losses. Crop rotation can sometimes accomplish this. It involves planting two or more cycles of a resistant crop in the interval between susceptible crops. In other countries rice, sorghum, cowpeas, peanuts, onions, and cabbage are often resistant to Meloidogyne spp. No research has been done to determine if these would be effective rotation crops here in Belize.

Contact nematicides are granular chemicals which are mixed with the soil to kill nematodes. They are often used in field crops and vegetable crops when nematodes are a problem and must be reduced to ecomomic levels. Several contact nematicides are available in Belize: (1) Mocap, (2) Terracur P (Dasnit), (3) Disyston, (4) Nemacur, and (5) Curater (Furadan). Of these only Mocap cannot be used on tomatoes and peppers. The latter three nematicides--Disyston, Nemacur, and Curater--are systemic chemicals which are absorbed by the roots and transported up the stem to the leaves and fruit. Systemic nematicides can be applied to vegetable crops in the seed bed or at transplant, but never later in the crop cycle. This is done to avoid the buildup of poisonous residues in the fruit or other plant parts that people eat. All of these nematicides are highly poisonous chemicals. In order to minimize the hazards and maximize (root-knot) nematode control, the label instructions must be strictly obeyed.

Plant breeders are discovering and developing varieties of tomato, sweet pepper, tobacco, soybeans, and dry beans that are resistant to Meloidogyne. Seed companies claim resistance for the follcwing market varieties of tomatoes:

Beef Master	New Splendor
Better Boy	Pelican
Bigset	President
Carmen	Terrific
Celebrity	University of Hawaii varieties... (N-5, N-11, N-52, N-65, N-69)
Contessa	
Glory	Vineripe
Hope No. 1	Wonder Boy
Master No. 2	Vista
Master No. 3	VFN-8
Monte Carlo	

All of these varieties except VFN-8 are hybrids. The seven underlined varieties yield well and have been grown in Belize. However, none of these varieties have actually been tested here for root-knot resistance.

PHYTOPHTHORA ROOT ROT OF PEPPERS & TOMATOES

Root rots are a serious plague of Capsicum peppers in Belize. One type of root rot is associated with bacterial wilt. This disease is described in another fact sheet. The other common root rot is caused by the fungus Phytophthora. Both sweet peppers and hot peppers (such as habañero) are susceptible to Phytophthora root rot. The disease also occurs on tomatoes, but more rarely.

Pepper trees are attacked both above-ground and below-ground by the fungus. Below ground, small roots and the tips of larger roots are rotted first. The rot travels slowly up one or more roots and eventually reaches the stem. Cankers (sunken areas of killed bark) appear near the base of the stem and may completely girdle the plant. Wilting, yellowing, and dropping of the leaves are common above-ground symptoms. Occasionally, dark cankers appear higher up on the stem or in the branches. They are especially common near the joints or branch unions. Fruits may also be attacked and rotted, although this is more common in tomatoes than in peppers.

Phytophthora root rot (PRR) is primarily a soil-borne disease. The fungus produces three types of spores. One type is a thin-walled spore which swims in the soil water and seeks out new roots to infect. Plants are most susceptible to infection after heavy rains or in poorly-drained soils. The two other spores are thick-walled and durable. They allow the fungus to survive long periods of time between crops. Although all three spores are produced in the soil, splashing water may carry them up into the plants. Fruit rots and branch cankers are the result.

When PRR first appears in a field, only a few plants may be affected. These are often located in low-lying or poorly-drained areas. The fungus builds up and persists in the soil if susceptible crops continue to be grown. It spreads to other parts of the field as contaminated soil is moved by farm impliments, footgear, and running water. After several years, a field may be extensively infested and crop losses severe. At this point, rotating to a new piece of land is the most practical control measure.

When selecting a new planting site, avoid soils that are excessively heavy, shallow, or poorly-drained. Ditches, cambered beds, or raised rows are some measures which can be taken to improve marginally suited land. Avoid transferring seedlings or soil from infested land to the new planting site. Infested land can be rehabilitated by growing crops for 2-3 years which are not susceptible to PRR. Most field crops (e.g, corn, sorghum, rice, and sugarcane), vegetables (with the exceptions of peppers, tomatoes, eggplants, etc.), and pasture grasses would be suitable rotation crops.

During the past 10 years, several fungicides have been developed which are extremely active against Phytophthora spp. Metalaxyl (Ridomil), propamocarb (Previcur-N) and fosetyl-Al (Aliette) are the best known members of this group. When applied to the soil, they may control PRR for 2-6 months. Unfortunately, these chemicals are expensive and have not

been approved for use in pepper production fields. Treatment of seedbed soils, however, is more common and would be economic. Soil fumigation is an alternative to these products in the seedbed. Soil fumigants such as methyl-sodium (Vapam) and methyl isothiocynate (Vorlex, Di-Trapex) have the added advantage of killing weed seed, harmful insects, and nematodes in treated soil. However, they are hazardous to use and require a waiting period of 2-4 weeks between treatment and planting. If none of these products are available, be sure to locate seedbeds away from producing fields and in an area where tomatoes and peppers have not been grown in the past.

Fruit rot and branch canker symptoms can be prevented by regular sprays of zineb, maneb, propineb (Anthracol), captafol (Difolatan), or chlorothalonil (Bravo, Daconil). The fungicide mixture described in the bacterial spot fact sheet should also be effective. Covering the soil surface with plastic or organic mulches is an alternative method of preventing Phytophthora fruit rot and branch cankers. No varieties resistant to this disease are available.

J.M., August 1986

APPENDIX III: PESTICIDE LIST

The following is a list of pesticides which are frequently or occasionally sold in Belize. Those denoted by a plus sign (+) have been mentioned in this paper or may be needed by project farmers sometime in the future. Common names, trade names, and basic manufacturers are given.

FUNGICIDES / BACTERICIDES

+benomyl — Benlate — DuPont

captafol — Difolatan — Chevron

captan — Captan — Chevron, Stauffer

+chlorothalonil — Bravo, Daconil — Diamond Shamrock (SDS Biotech)

+mancozeb — Dithane M-45, Manzate 200, Nemispor — DuPont, Rohm & Haas

+metalaxyl + mancozeb —Ridomil MZ58WP — Ciba Geigy

+PCNB — Terrachlor —Olin Mathieson, Bayer

propineb — Anthracol — Bayer

thiram — Thylate — DuPont

basic copper sulfate — Basic copper sulfate — Phelps Dodge

copper ammonium carbonate — Copper-Count-N — Mineral R & D Corp.

+copper hydroxide — Kocide 101, Cupravit Blue — Kocide Corp., Bayer

copper oxychloride — Cupravit Verde (Forte) — Bayer

streptomycin sulfate + copper —Agrimycin, Ultramycin — Pfizer

INSECTICIDES

aldrin — Aldrin — Shell

+azinphos-methyl — Gusathion, Guthion — Bayer, Mobay

+carbaryl — Sevin — Union Carbide

+diazinon — Diazinon, Spectracide — Ciba Geigy

gamma BHC — Lindane — Chevron, ICI

malathion — Malathion, Cythion — American Cyanamid

methamidophos — Tamaron, Monitor, MTD — Bayer, Mobay

+methomyl — Lannate — DuPont

+methyl parathion — Folidol M, Penncap M — Bayer, Pennwalt

mirex — Mirex — Allied Chemical

monocrotophos — Nuvacron, Azodrin — Ciba Geigy, Shell

+oxamyl — Vydate — DuPont

+oxydemethon-methyl — Metasystox R — Bayer, Mobay

Insecticides...continued

+permethrin — Ambush, Pounce — ICI, FMC
phoxim — Volaton — Bayer
primiphos-methyl — Actellic — ICI
propoxur — Baygon, Undene — Bayer, Mobay
+trichlorfon — Dipterex —Bayer, Mobay
+toxaphene — Toxaphene — BFC, Inc.

SYSTEMIC INSECTICIDES / NEMATICIDES (soil applied)

+carbofuran — Furadan, Curater — FMC, Bayer
disulfoton — Di-Syston — Bayer, Mobay, Sandoz
fenamiphos (phenamiphos) — Nemacur — Bayer, Mobay
+oxamyl — Vydate — DuPont

CONTACT NEMATICIDES and/or INSECTICIDES (soil applied)

+ethoprophos — Mocap — Rhone Poulenc
fensulfothion — Terracur P, Dasnit — Bayer, Mobay
+phorate — Thimet — American Cyanamid

SOIL FUMIGANTS

D-D — Vidden D — Shell. Controls nematodes & soil insects only.
metham-sodium — Vapam — Stauffer
+methyl bromide — Dowfume MC-2, Brom-O-Gas — Dow, Great Lakes Chemical
+methyl-isothiocyanate — Vorlex, Di-Trapex — Nor-Am, A.G. Schering

HERBICIDES

+alanchlor — Lasso — Monsanto
+a metryn — Gesapax, Evic — Ciba Geigy
atrazine — AAtrex, Gesaprim —Ciba Geigy
2,4-D — many trade names and manufacturers
+DCPA — Dacthal — Diamond Shamrock (SDS Biotech)
+diphenamid — Enide — Upjohn
diuron — Karmex — DuPont
+fluaziprop-butyl — Fusilade — ICI
+glyphosate — Roundup — Monsanto

ioxynil — Actril — May & Baker

+paraquat — Gramoxone, Mil-Quat — ICI, Mill Creek Products

picloram — Tordon — Dow

propazine — Milogard — Ciba Geigy

+trifluralin — Treflan — Elanco