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FEASIBILITY STUDY ON THE POTENTIAL BENEFITS OF JOINT AGRICULTURAL RESEARCH AND EDUCATION IN THE CARIBBEAN BASIN REGION

A REPORT TO THE 101st CONGRESS OF THE UNITED STATES

May 1, 1990

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LIST OF ACRONYMS

ADF	Agricultural Development Foundation (Dominican Republic)
AID	Agency for International Development
APHIS	Animal and Plant Health Inspection Service
AREP	Agricultural Research and Extension Project (of RDO/C)
CAAP	Private Agricultural Agroindustrial Council
CAEP	Caribbean Agricultural Extension Project (of RDO/C)
CARDI	Caribbean Agricultural Research and Development Institute
CARIRI	Caribbean Industrial Research Institute
CATCO	Caribbean Agricultural Trading Company
CATIE	Tropical Agricultural Research and Training Center
CBAG	Caribbean Basin Advisory Group
CBI	Caribbean Basin Initiative
CDB	Caribbean Development Bank
CSRS	Cooperative State Research Service (of USDA)
CTA	Center for Tropical Agriculture (in IFAS)
EAP	Pan American Agricultural School (Zamorano)
EARTH	Agricultural School for the Humid Tropics
FAMU	Florida A&M University
FAO	Food and Agriculture Organization of the United Nations
FHIA	Honduran Agricultural Research Foundation
FRED	Food and Resource Economics Department (in IFAS)
FPX	Federación de Asociaciones de Productores y Exportadores Agropecuarios y Agroindustriales de Honduras (formerly, FEPROEXAAH) (Honduras)
FUSADES	El Salvadoran Economic and Social Development Foundation
GDP	Gross domestic product
Gremial	Guild of Non-traditional Product Exporters (Guatemala)
IADB	Inter-American Development Bank
ICAITI	Instituto Centroamericano de Investigación y Tecnologia Industrial (Guatemala)
ICTA	Instituto de Ciencia y Technologia Agricola
IFAS	Institute of Food and Agricultural Sciences (at UF)
IPM	Integrated pest management
IICA	Inter-American Institute for Cooperation on Agriculture
ISA	Superior Institute of Agriculture (Dominican Republic)
JADF	Jamaica Agricultural Development Foundation
JAREF	Joint Agricultural Research and Education Feasibility Study
LSU	Louisiana State University
MOA	Ministry of Agriculture or its equivalent
NGO	Non-government organization
NTAE	Non-traditional agricultural export
OECS	Organization of East Caribbean States
PROEXAG	Non-traditional Agricultural Export Support Project
R&D	Research and Development
RDO/C	A.I.D. Regional Development Office for the Caribbean

REAC	Research and Education Advisory Council
ROCAP	U.S.A.I.D. Regional Office for Central America and Panama
TAMU	Texas A&M University
TARS	Tropical Agricultural Research Station
TREC	Tropical Research and Education Center
TROPRO	West Indies Tropical Produce Support Project
UF	University of Florida
UPR	University of Puerto Rico
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
UVI	University of the Virgin Islands
UWI	University of the West Indies
WB	World Bank
WINBAN	Windward Islands Banana Producers Association

EXECUTIVE SUMMARY

The purpose of this study, as requested of A.I.D. by the 101st Congress of the United States, is to assess the feasibility and potential benefits of joint research and education on common problems facing agricultural producers in the Caribbean Basin, including producers in Central America, the Caribbean, and U.S. states abutting the Gulf of Mexico. The report focuses on common problems facing growers of tropical fruits, vegetables, and ornamentals.

A. Principal Findings

The study found specific problems common to Caribbean Basin and U.S. producers in states abutting the Gulf of Mexico. The most critical common problems are plant protection, including pesticide residues within tolerances; postharvest handling; and production constraints. Other problems common to horticultural producers, while less problematic to U.S. producers, are crop selection, transportation, market penetration (especially market intelligence, market linkage, quality control), and food processing technology.

The study found that research on and technology development and marketing for horticultural crops in the Caribbean Basin region are primarily carried out by the private sector as part of specific export commodity systems and organizations. In Central America and the Caribbean, public sector research and education institutions largely have focused on traditional export (banana, coffee, cacao) and food crops (grains), although some of these institutions are now developing research programs in support of development of non-traditional agricultural exports (NTAE) crops. But this research often is not coordinated or closely linked to grower needs, indicating a significant limitation in the technology development and transfer system for horticultural crops intended for NTAE markets. In the United States, public institutions are engaged in research on horticultural crops but relatively little of this research is carried out collaboratively or jointly with Central American or Caribbean researchers.

Although many production and marketing factors limit horticultural crop development in the Caribbean Basin region, the findings of this study strongly suggest that research and education efforts should focus on plant protection, postharvest handling technology, and production constraints. While there are differences between Caribbean Basin and U.S. producers of horticultural crops, all production and marketing participants share a concern in overcoming the problems identified. Cooperation through joint research and education could facilitate the development and transfer of technology that producers and other market participants require to enter and compete effectively in the marketplace.

B. Major Conclusions

There is a need for improved links and communication between technology developers, suppliers, and users to facilitate research on problem areas of common concern. This could be stimulated by a mechanism that (1) ensures systematic dialogue between public and private research and educational institutions; (2) strengthens the role of the private sector in establishing research priorities and in providing funding support for research; and (3) directly participates in technology transfer to producers through education, extension, and other means as appropriate.

The study evaluates four options for establishing a mechanism to address this identified need: (A) a new research and education center; (B) a new organizational unit within an existing research and education center; (C) strengthening research and education programs of existing research and education institutions; and (D) establishing a joint research and education program coordinated by a private international horticultural industry group. Each option was evaluated in terms of four criteria (staffing, coordination, likely impact, and cost).

Generally, significant limitations were found to be associated with establishing a new research and education center (option A) or a new organizational unit within an existing research and education center (option B). Option C provides a model of how donors might play a more active role in strengthening research and education programs of existing research and education institutions. In this model, however, the private sector's role is largely advisory, with the private sector having little, if any, direct control over how scarce research funds would be allocated. By comparison, option D provides for research funding to be channelled through a research and education program coordinated by a private international horticultural industry group. In so doing, option D provides a strong link between technology users in the private sector and researchers in the public and private sectors. This option also will serve to coordinate and strengthen research and education programs of public sector regional institutions.

Option D would provide, at least in the short run, an effective and efficient mechanism for getting agricultural researchers to focus more directly on the common problems that are of greatest concern to Caribbean Basin and U.S. horticultural crop producers. However, in the long run, the progress in technology development and transfer achieved through option D could be enhanced to the extent that the public sector research and education institutions participating in the program would be part of an overall horticultural research and education network such as that outlined in option C.

SECTION I

INTRODUCTION

A. Purpose of Study

The purpose of the study, as requested of A.I.D. by the 101st Congress of the United States, is to assess the feasibility and potential benefits of joint research and education on common problems facing agricultural producers in the Caribbean Basin, including producers in Central America, the Caribbean, and U.S. states abutting the Gulf of Mexico. The report focuses on common problems facing growers of tropical fruits, vegetables, and ornamentals.

B. Background

The 101st Congress, in the FY 1990 Appropriation bill, noted that agricultural producers in the Caribbean region, including Caribbean Basin Initiative (CBI) countries and the U.S. states abutting the Gulf of Mexico, have common prospects and problems. The Congress noted the following as potential common problems: proper crop selection and management, pest management, postharvest handling and treatment, transportation, and market penetration. Further, the Congress cited, as an example of a common problem, the declining research on and availability of environmentally safe pesticides and pest management technologies. The Congress expressed the view that it would benefit Caribbean and U.S. agricultural interests to seek solutions to common problems jointly.

The Congress directed the Agency for International Development (A.I.D.) to study the feasibility and the potential benefits to U.S. agricultural production and the objectives of the CBI of joint research and education on agricultural problems common to agricultural producers throughout the Caribbean Basin region. Responding to this requirement, A.I.D. mounted the Joint Agricultural Research and Education Feasibility (JAREF) study. For the interested reader, more detailed technical information about the study can be found in the JAREF Technical Report and annexes (153 pages), on file with A.I.D.'s LAC/DR/RD office. Table 1 list the annexes to this report.

The term "joint research and education," while not defined by Congress, is understood as meaning that U.S. researchers (or educators) collaborate with colleagues in Central American and Caribbean research and education institutions to develop agricultural research and/or education programs on problems common to Caribbean Basin producers. The study, according to the scope of work, assesses the role of public research and education in technology development and transfer for horticultural crops

Table 1.	Annexes Available From A.I.D.'S LAC/DR/RD
Annex 1	Congressional Requirement for JAREF Study
Annex 2	Study Methodology
Annex 3	Profile of NTAE Production in Each Sub-Region
Annex 4	Other Common Problem Areas and Potential Benefits of Joint Research and Education 1. Crop Selection 2. Transportation 3. Market Penetration 4. Food Processing Technology 5. Technology Transfer 6. Organizational and Policy Constraints
Annex 5	Major Diseases of Tropical Fruits
Annex 6	A Partial Listing of Pests Attacking a Number of Commonly Grown Fruits in the Caribbean Basin Region
Annex 7	Principal Research Mandate of Research and Education Institutions Visited and/or Reviewed
Annex 8	Common Problems and Institutional Responses to NTAE Crops by Caribbean, Central American, and U.S. Southeast Research and Education Institutions
Annex 9	Major Problems in Agricultural Research and Education in the Caribbean Basin Countries
Annex 10	Economic Returns to Research and Education on NTAE Crops
Annex 11	Potential Contributions to Caribbean Basin Initiative (CBI) Objectives and U.S. Agricultural Production
Annex 12	Sustainability of Joint Research and Education
Annex 13	Site Visits and Key Informants Interviewed
Annex 14	Key Informants Interviewed by Telephone
Annex 15	Key Informants Who Replied by Letter
Annex 16	Key Informants Who Replied by FAX

(see subsection B.3. below), but the private sector finances and/or conducts a substantial portion of horticultural research in the Caribbean Basin region. However, the limited time and resources available to conduct this study precluded a full assessment of private sector agricultural research and education underway in the region.

1. Caribbean Basin Region: Geographic Overview

The Caribbean Basin region is defined as including:

- Central American countries: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama;
- Caribbean countries: Aruba, Bahamas, Barbados, British Virgin Islands, Dominican Republic, Haiti, Jamaica, Netherlands Antilles, Trinidad and Tobago, and Eastern Caribbean states (Antigua and Barbuda, Dominica, Grenada, Montserrat, St. Christopher-Nevis, St. Lucia, and St. Vincent and the Grenadines); and
- U.S. states abutting the Gulf of Mexico: Alabama, Florida, Louisiana, Mississippi, and Texas. Although not U.S. states, Puerto Rico and the U.S. Virgin Islands also are included.

These countries are identified in the map on page 8, which also shows the acronyms of the key research, education, and export development organizations in the Caribbean Basin region and of major A.I.D.-assisted projects and institutions working on development of non-traditional agricultural export (NTAE) crops in the region. A brief description of these various organizations and projects is provided in the appendix of this report.

2. CBI Objectives

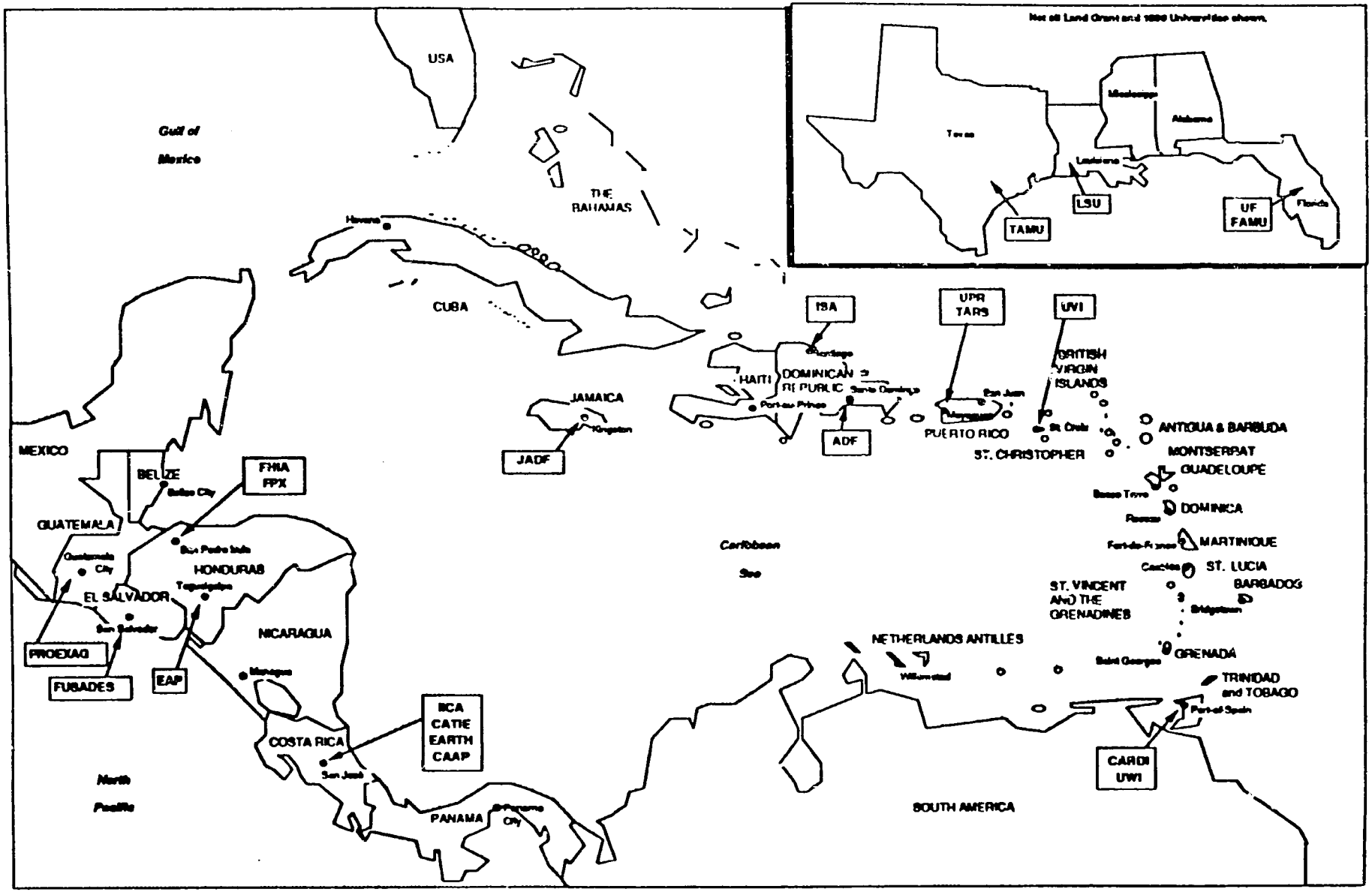
The objective of CBI is to promote economic development through private sector initiative in Central America and the Caribbean. The goal is to expand foreign and domestic investment in non-traditional sectors, diversifying CBI country economies and expanding their exports. Herein, the term "Caribbean Basin" refers in a general way to the Caribbean and Central American countries participating in the CBI program, while the term U.S. Southeast refers to the U.S. states abutting the Gulf of Mexico.

3. Rationale for Focus on Horticultural Crops

A variety of agricultural commodities are produced in the Caribbean Basin region; they include livestock, food and fiber crops (exclusive of horticultural crops), and horticultural crops, including fruits, vegetables, and ornamentals. With the economic opportunities (e.g., foreign exchange) created in the

Central American and the Caribbean countries by CBI, A.I.D. has placed increasing emphasis on horticultural crops with export potential. Accordingly, this study focused on the potential benefits of joint research and education on common problems facing Caribbean Basin and U.S. producers of horticultural crops.

Research, Education, and Export Development Organizations in the Caribbean Basin Region



SECTION II

OVERVIEW OF CARIBBEAN BASIN HORTICULTURAL PRODUCERS

A. Comparison of CBI and U.S. Horticultural Producers

Many farmers in the Caribbean Basin region are actively involved in producing horticultural crops. However, the total volume of horticultural crops that they supply to the U.S. market comprises only a small percentage of the total horticultural crops marketed in the United States. In recent years, Central American and Caribbean horticultural growers have shifted toward production of horticultural crops to meet growing market demand for these commodities in the United States and elsewhere. This trend implies a need throughout the region for additional research and education on how to grow and market these crops most efficiently.

The study found major differences in the three Basin sub-regions (Caribbean, Central America, and the U.S. Southeast) in the production and marketing environments faced by horticultural crop producers. Generally, horticultural producers in the CBI countries, relative to horticultural producers in the U.S. Southeast, face a less favorable production and marketing environment with respect to access to improvements in cropping technology and management systems, postharvest handling and processing technologies; and credit and agricultural inputs, transportation, markets, and research and extension.

With respect to agroclimatic conditions, the land tilled by U.S. farmers in the states abutting the Gulf of Mexico, with a few exceptions, is located within a temperate climatic zone in which crops can be grown only during the spring, summer, and fall months. However, the southernmost parts of both Florida and Texas have sub-tropical climates, with very infrequent freezing weather. These areas can grow many tropical crops that cannot thrive elsewhere in the continental United States. The lands cultivated by farmers in the CBI countries are in a tropical climatic zone in which crops can be grown the year round. This places CBI producers in an advantageous position to supply horticultural produce to the United States during those times of the year when U.S. farmers are not able to produce certain crops or to grow sufficient supply to meet market demand.

However, for various reasons including agroclimatic differences, producers in CBI countries cannot simply adopt U.S. horticultural production systems. These systems must be developed or adapted to fit the specific agroclimatic niches of each production plot. Thus, the farmer cannot use the same technology to grow the same crop on all plots. Hence horticultural growers in CBI countries need to adapt production technologies to the resource mix of each plot, thereby increasing

the complexity of the management systems required to support production.

With respect to access to public/private research and extension, horticultural producers in the U.S. Southeast are served by a well-developed agricultural research, extension, and education system (Land Grant universities and other educational institutions). Farmers are well educated and have ready access to agricultural information sources through a variety of media, including contacts with research scientists in the university and USDA research systems. Further, agricultural extension agents, backed up by subject matter specialists, are assigned to each district. Finally, private firms that sell inputs or equipment to or buy produce from farmers have a vested interest in ensuring that farmers have the information needed to be able to grow top quality produce profitably.

By comparison, public and private sector sources of agricultural information are much less developed in the CBI countries. In many of these countries, research and extension budgets often are barely sufficient to cover salaries, with little left for research and extension expenses. Public sector research and extension tend to focus on traditional subsistence food crops and not on horticultural crops. Only farmers and entrepreneurs having sufficient resources to establish connections with U.S.-based information sources (e.g., U.S. universities, importers of horticultural crops, or private consultants) or with private sector companies in CBI countries can obtain the basic technology and inputs required to establish adaptive research and commercial production and exporting programs.

B. Common Problems Facing Horticultural Producers

Despite the differences between horticultural producers in the CBI countries and the U.S. Southeast, all horticultural producers, including farmers, growers, packers, processors, shippers, transporters, and importers, share a common concern in terms of overcoming problems that constrain efficient production and marketing of their crops in an increasingly competitive and interdependent global economy. This concern is most critical where producers face problems common to all three Caribbean Basin sub-regions.

The essential prerequisite for a successful horticultural enterprise is the ability to provide the market with a consistent supply of high quality products over an extended time. Meeting this prerequisite is a challenge facing all horticultural growers throughout the Caribbean Basin region. Insufficient product quantity or quality may be due to a number of problems commonly found in many Caribbean Basin countries.

Based on document reviews, site visit observations, and discussions with key informants, nine potential common problems were identified as follows: crop selection, production constraints, plant protection, harvesting/postharvest handling and management, transportation, market penetration, food processing technology, technology transfer, and organizational and policy constraints.

These problems were ranked in terms of three factors: (1) the immediate economic impact of the problem in the region (e.g., opportunity to earn foreign exchange); (2) the urgency of the problem (e.g., potential for environmental damage); and (3) the existence of a minimum institutional base for conducting technology development and transfer on the problem. Based on this ranking, described in detail in annex 4, three priority common problems were identified.

1. Plant protection,
2. Harvesting/postharvest technology and management, and
3. Production constraints.

These problems were found to place the most immediate constraints on successful horticultural industry development throughout the Caribbean Basin region, including U.S. states abutting the Gulf of Mexico. A basic theme underlies them, namely, that while the market demands a consistent supply of quality products, this goal cannot be attained without adequate use of postharvest technology in combination with plant protection and appropriate production technology.

Each common problem is now reviewed, with the order of presentation--plant protection, harvesting/postharvest technology and management, and production constraints--being a general order of importance of these common problems across all three sub-regions of the Caribbean Basin. At the same time, it should be noted (1) that not all horticultural producers place equal importance on any given common problem, and (2) that producers in the region also share concerns about other problems.

1. <u>Plant Protection</u>

CBI and U.S. horticultural crop producers face a major problem with respect to pest and disease management. Cultivars resistant to pests and diseases may be available for some crops, but in most cases the use of chemical pesticides currently is the only way to achieve economic control. Growers must apply pesticides at dosages sufficient to control pests, but not so high as to leave residues that exceed the tolerances of importing countries. The absence of pesticide registration for many horticultural crops limits pest management practices.

There is almost a total dependence on chemicals for pest and disease control, because of the availability and success of chemicals in crop protection. There is also a general lack of awareness of alternative control strategies for particular pest situations. Even when such alternative strategies are known, they have not been widely implemented. Biological control is not a system that can be adopted readily by small-scale farmers. Integrated pest management (IPM) combines a variety of control techniques to reduce/keep pest populations to acceptable levels. Pesticides are used only when the pest population reaches an infestation level at which the economic loss of not applying the required control would be greater than the cost of applying the control. Crops must be monitored regularly for pests and pest damage. IPM can provide an environmentally sound, cost-effective approach to control a wide variety of pests in a large number of crops, but lack of data in many areas of IPM limits the application of this tool in the Caribbean Basin region.

Most estimates of perishable crop production losses attributable to pests average from 25 to 35 percent, although precise data are not currently available. Postharvest losses of perishables from insects and diseases have been estimated to be 40 percent or more in CBI countries. It has been estimated that pests and diseases in Dominica cause a 50 percent loss in fresh fruits and vegetables. In addition, one must consider the cost of control practices, limitations or rejections of exports, the adverse impact on human health from pesticide poisoning, and inherent environmental contamination problems.

Because of insufficient research and extension, over-application of pesticides is a common problem. Also, excessive pesticide application can lead to development of resistance to pesticides in the pest to be controlled and the acquisition of pest status by previously harmless species (e.g., whitefly).

Tropical insect fauna are poorly known, and in some cases basic taxonomic studies simply have not been done. There is also the problem of where and to whom to turn for help in identification. A tropical insect taxonomic and identification center is urgently needed in the Caribbean Basin region.

A very serious problem for Caribbean Basin producers is the difficulty of obtaining the latest pesticide registration and tolerance information for horticultural crops, in order to satisfy EPA and FDA import requirements. Growers have suffered considerable losses because of loads rejected at the port of entry into the United States owing to illegal chemical usage or residue levels exceeding tolerance. In most cases, this is due to a lack of knowledge of the latest U.S. pesticide laws. U.S. producers also are concerned as they seek alternate pest management technologies to replace pesticides which are now or may become banned.

2. Harvesting/Postharvest Technology and Management

Success in any horticultural production and marketing operation is determined, to a significant extent, by postharvest handling; that is, by how the crop is handled (packed, stored, shipped, etc.) between the time that it is harvested and the time that it is sold to the consumer. However, little effort has been directed at improving postharvest handling systems in the CBI countries. U.S. horticultural producers also need improved postharvest handling technology to ensure their crops meet the requirements of destination markets within the U.S. and internationally. For example, the technology for handling mixed loads of fresh fruits and vegetables to small island states needs to be improved. The need for improved postharvest handling technology and management of horticultural crops is even greater in the CBI countries.

Correct harvesting techniques are directly related to market requirements. Major losses have occurred as the result of inappropriate harvesting procedures. The most serious problems are related to improper harvesting and field selection, improper packing schedules relative to market conditions, lack of knowledge of broker standards, and inadequate mechanisms for quality-control checks and feedback.

Producers, handlers, and consumers all place high importance on loss reduction, food quality (including safety aspects), and freshness of horticultural crops. Yet understanding the underlying biology of these crops is essential to developing and applying new or improved technologies in all aspects of handling, storage, and distribution of fresh horticultural commodities. Such commodities are composed of living, metabolizing tissues having a variety of characteristics, including their capacity to withstand the stresses of time, temperature, physical handling, and transport; to resist infection and/or spoilage by decaying organisms; and to develop and maintain quality. These characteristics constitute the basis for determining the requirements for successful storage, handling, and distribution.

All the care taken in producing a crop may be lost through poor postharvest handling practices. Horticultural crops are usually very perishable and even a few hours of postharvest mismanagement can significantly lower the quality and marketability of the commodity. Common problems facing growers of horticultural crops include inadequate precooling to remove field heat, lack of organization in grading and packing, use of improper packaging materials that are not designed to provide adequate ventilation or protect the contents against bruising during transit, improper storage temperature and humidity management, and incompatibility of mixed load storage. Postharvest technology is probably the universal weak link in the chain from production to consumption of horticultural crops.

The "brick and mortar" approach consisting of infrastructure investments such as cooling facilities, storage rooms, packing houses, and other related equipment is often underutilized or misused because of inadequate management capability. It is common to see vehicles waiting to be unloaded at the packing house in 35°C heat because of poor logistic and time control procedures or storage of commodities in a variety of incompatible cooling facilities.

Advancements have taken place in postharvest infrastructure in the CBI countries (e.g., pineapples in the Dominican Republic, melons in Central America, and bananas in the Windward Islands). But in general, postharvest systems have not been designed for specific crop needs and required equipment is often unavailable. Existing infrastructure, including marketing board facilities, and internal buying depots, is underutilized and cooling facilities for extra-regional shipping are lacking.

The lack of cooling facilities also has intensified losses related to unreliable air transportation. Highly perishable products often arrive at the airport with high pulp temperature, and any delays in air transit permit further deterioration. In recent years private companies have increased cooling and freezing facilities, particularly in Central America. In the Eastern Caribbean, there is a lack of refrigerated storage for fruits or vegetables, usually at both producing and receiving points. Common problems are the location, adaptability, and utilization of the infrastructure in order to maximize returns on investment. The management of these facilities is often the most difficult problem to overcome. A problem in several countries visited was the poor management and organization of packinghouse facilities.

3. Production Constraints

Beyond the specific problem of plant protection (discussed above), Caribbean Basin horticultural producers also face common production constraints of various types. For example, citrus and mango trees are subject to serious decline problems just as they reach production age in both the Caribbean and the U.S. Gulf Coast states. Studies of the problem in the United States repeatedly have been confounded by cold damage due to recurring freezes. This problem would be eliminated or reduced if some of this research were carried out in a warmer zone of the Caribbean Basin region.

Another serious problem in increasing fruit production is the availability of reliable, disease-free sources of budwood and rootstock seed. Mistakes made early in a tree's life cannot be reversed, and sound propagation material is the basis for successful production and marketing. Genetic advances with different varieties that are more resistant to pests and diseases and that facilitate biological control of such problems are of

major concern to CBI and U.S. producers, particularly in Florida. All Caribbean Basin producers want varieties that have higher tolerances and resistance to pests and diseases.

Another problem faced by CBI and U.S. producers is that of acquiring crop production technology to support diversification away from traditional monocropping systems. While fruit and vegetable varieties have a theoretical yield potential controlled by the genes of the plant, rarely is this yield achieved because of climate, soil, and cultural factors that affect plant growth and productivity.

Many Caribbean Basin producers have relatively poor land available for planting. Soils may be low in fertility and have poor structure, poor drainage, and/or excess salinity. In Central American and Caribbean countries, fields often are too hilly for continuous row culture. Nearly all areas where horticultural crops are grown have periods of inadequate or excess precipitation, and irrigation and/or drainage control is needed to avoid yield reductions and adverse effects on crop quality. Tile and ditch systems can help minimize the effects of excessive rain. Raised beds can alleviate waterlogging.

A common problem among vegetable growers is whether to use hybrid seed or open-pollinated seed. Hybrid seed, much more expensive than open-pollinated seed, may offer advantages in terms of increased earliness, resistance to stress, and uniformity of product. However, production inputs need to be at a higher level (i.e., more fertilizer, irrigation, herbicides) in order to realize the potential of hybrid seed. In many cases, the less expensive open-pollinated seeds perform better under low and medium input technologies.

The economic success of production depends on the ability to produce and deliver a crop to market on a timely basis. This, in part, depends on getting the crop to its market destination at a time when there is minimal competition from other sources. Poor timing of farm operations and improper site selection in many CBI countries leads to lack of continuity in supply and missed market opportunities. Lack of knowledge of plant habit manipulation (pruning, training practices) is a severe limitation on many CBI tropical fruit growers.

Production constraints are also a common problem for U.S. growers. Land Grant universities in the Southeast allocate millions of dollars and numerous scientist years to carry out research and develop information to be given to local growers on soil modification, irrigation and soil drainage technology, prevention of soil salinity, plant spacing, fertilization, crop rotation sequences to minimize pest buildup and chemical residue carry over, and training/pruning practices to optimize plant form for maximum yield. These applied research programs conducted by

U.S. universities have been an integral part of the U.S. horticultural crop industry success story over the past 100 years.

Fruits and vegetables on hundreds of soil types in the Southeast are grown. Soil type and pH affect yield and crop quality. Most fruit and vegetable crops are more productive on particular types of soil. Root crops are affected by the physical properties of the soil. Carrots grown on heavy clay soils tend to be short and misshapen. In order to obtain maximum yields, CBI and U.S. producers need to be more knowledgeable about how to select crops to match the soil type.

Another common problem is utilization of soils with the incorrect pH. Most horticultural crops require a pH of 6.5 to 6.8. Inadequate application of lime or sulfur to amend the soil pH is a factor limiting yield potential. Growers are not always knowledgeable about the amount and timing of fertilization applications, or about how to counteract deficiencies in various major and minor elements that restrict yield. The interaction of soil fertility problems with deficiencies or excesses in soil moisture result in serious plant stresses which adversely affect yield.

U.S. growers are often faced with frost protection problems, a problem that is also common to Central American growers at higher elevations. Mulches, tents, row covers, and sprinkler irrigation can help warm the soil and air around the plants and protect them from cold temperatures.

SECTION III

RESEARCH AND DEVELOPMENT IN THE CARIBBEAN BASIN REGION

Section II identified the priority common problems that face Caribbean Basin producers of tropical horticultural crops. This section assesses the level of activity of research and development (R&D) on the priority common problems with development including both technology transfer and education.

Based on information available in secondary documents, the site visits to research and education institutions in the Caribbean Basin region, and interviews with key informants, the status of R&D on common problems facing Caribbean Basin horticultural crop producers was assessed (see annex 8). Each common problem was rated in terms of the extent to which the institutions reviewed are responding to each of the common problems identified, with the ratings assigned in terms of three levels of activity (limited, some, and considerable).

For the interested reader, the appendix provides a brief introduction to the institutions reviewed; however, the analysis does not cover the great variety of private sector organizations that carry out technology development and transfer activities for horticultural crops.

Support for research on and development of horticultural crops in the Caribbean Basin region is not new. For example, in the case of melons, much of this research over the years has been carried out by individual entrepreneurs or by organizations, including multinationals (e.g., United Brands), independents (such as Central American Produce Company), and farmer cooperatives (Byrnes, 1989). This technology development and transfer process occurs in a similar manner for other crops such as berries, asparagus, and winter vegetables. Also, a great deal of research is carried out by seed companies and suppliers of other agricultural inputs such as fertilizers and pesticides, including herbicides and insecticides.

While the private sector has been active in developing adaptive research on horticultural crops in the Caribbean Basin region, public sector research and education organizations in the region have focused primarily on traditional food or import substitution crops. Yet, as Table 2 shows, there are many examples of collaborative research on horticultural crops by national or regional organizations, U.S. universities, and others (e.g., the USDA). More recently, research interest in CBI countries has been stimulated by various projects, primarily supported by donors but also by investment initiatives of agricultural entrepreneurs within the region.

Table 2. Examples of past or ongoing research and extension projects on horticultural crops.

* Macadamia--Research started in Costa Rica in 1966 with help from IICA, University of California, University of Hawaii, and others. In 1988, with U.S.A.I.D. support, greater emphasis was placed on the export marketing of macadamia.

* Germplasm--IICA/CATIE have collected germplasm of 400 species. Most of the collection is related to traditional crops, many of which are of significant economic importance.

* Integrated Pest Management (IPM)--In 1984, U.S.A.I.D./ROCAP began an IPM project with CATIE; this activity is now being expanded in the region, including participation by EAP, FHIA, and PROEXAG.

* Caribbean Food Crop Society (CFCS)--This network has existed for 25 years, providing a forum for the exchange of information on research and extension through annual meetings.

* University of Florida (UF)--UF has worked more than 30 years with the Pan American School of Agriculture (EAP), Honduras, in training, faculty exchange, and institutional development.

* The University of the West Indies (UWI)--U.S.A.I.D., in cooperation with the Midwest Universities Consortium for International Activities (MUCIA), collaborated with UWI in strengthening a regional agricultural extension program during a 10-year period.

* CARDI--This organization has received extensive support from U.S.A.I.D. and U.S. universities in research and extension and improved management of the institution.

* Caribbean Basin Advisory Group (CBAG)--This program was authorized in 1966, with the initial funding allocation made in FY 1974. CBAG supports research in tropical and subtropical agriculture by U.S. universities working in collaboration with Caribbean universities.

* IICA and the Caribbean Development Bank (CDB)--In response to the Crop Diversification program of OECS countries, these two organizations conducted a major study on fruit crop development for domestic and export markets.

* FHIA--A.I.D. support to this private agricultural research organization in Honduras is aimed at crop diversification includes a focus on horticultural crops.

Further, the Ministries of Agriculture in several countries have designated certain crops as priorities for export. But in most instances this interest has not progressed to specific research plans or their implementation. This is due to a number of reasons, including underfunded programs, limited training, and emphasis placed on subsistence food crops (e.g., grains), traditional export crops, and import substitution crops. Consequently, very little research has been undertaken on horticultural crops. Accordingly, transfer of technology from public sector research for such crops has been minimal.

Large multinationals and major independent companies are involved in adaptive research as well as technology transfer for horticultural crops; however, the information generated is often proprietary and generally not being tapped by or made readily available to the public except through product sales.

Most of the national research institutions, especially in Central America and the Dominican Republic, have initiated some research related to horticultural crops. FHIA in Honduras, ICTA in Guatemala, and ISA in the Dominican Republic have demonstrated capability, particularly at the production level. However, none of the research institutions has significant levels of research in postharvest handling, transportation, or market penetration.

National universities generally allocate limited resources for research and education on horticultural crops; where research is underway, it generally is being conducted in production areas such as pest management. Postharvest handling technology, transportation, and marketing areas are not adequately covered.

Other institutions in the CBI countries are involved in research or extension work, but were not investigated during this study because of time limitations. A few are doing research and training on horticultural crops. For example, ICAITI has been developing processing and food science technologies. This is a very important area for establishing a competitive edge for CBI countries.

Export development agencies in the region (CAAP, Gremial, FPX, and FUSADES) are relatively new. They were not designed and are not geared to carry out research but, in some cases, have undertaken a small amount of research through contracts, primarily with universities and consultants. Their strength lies in assisting potential growers to link up with buyers and importers in destination markets, to tap into existing technologies in the United States, and to assist in carrying out adaptive trials as part of their export development programs.

The lack of a transfer system for research and extension information within and across countries is one of the most serious problems in the Caribbean Basin region. One key aspect is the validation of technology at the local level. Some

technology packages have disrupted traditional farming systems, causing more harm than good. The lack of efficient transfer of information and technologies is a principal factor limiting the production and marketing of horticultural crops.

While IICA has a presence in the Caribbean, Central America, and the United States, it is not involved in hands-on production research, as it works primarily on developing institutional systems for the generation and transfer of technology through research and training. A primary focus of IICA's efforts is agricultural research management and organization. IICA also has a marketing program that focuses on international trade and policy issues as well as the emerging NTAE area.

CATIE is the primary research and graduate training institution in Central America; the University of the West Indies plays this role in the Caribbean. Both institutions have limited involvement in direct extension. CATIE utilizes pilot project areas and education as tools for technology transfer. The EAP (El Zamorano) is dedicated principally to training but also has been developing research and education programs on IPM. It also is in the process of expanding a research program related to postharvest handling and processing.

In the Caribbean, CARDI is primarily responsible for the transfer of technology but has limited emphasis on horticultural crops. CARDI's strategic plan places greater emphasis on horticultural crops, in order to develop technology that will help countries in the region to increase foreign exchange earnings. Under the Agricultural Research and Extension Project (AREP), A.I.D.'s Regional Development Office for the Caribbean (RDO/C) will be providing funds to strengthen CARDI's efforts in research and extension on horticultural crops. This is part of an overall diversification effort in the region. Over the past decade, the University of the West Indies developed a strong extension training and communication support capability under the A.I.D.-funded Caribbean Agricultural Extension Project (CAEP), although this project was aimed primarily at subsistence food crops.

PROEXAG (in Central America) and CATCO (in the Caribbean) are the main regional initiatives focusing on horticultural crops with a market-led approach. Much of their activities are focused on postharvest handling, transportation, and market penetration problems. Contrasted to the aforementioned research and education institutions, these organizations focus on commercial marketing business and export market development.

With respect to U.S. universities, several characteristics are summarized here:

- U.S. universities are strong in all areas of horticultural crops, having carried out considerable research,

teaching, and extension on all aspects of fruit and vegetable production, postharvest technology, crop selection, pest management, food processing, and technology transfer. Efforts in these areas have included ongoing projects over the past 100 years in Colleges of Agriculture. There is little duplication of research on horticultural crops, although educational and extension programs are similar among universities.

- With the exception of market analysis and related policy issues, U.S universities are weak in the areas of transportation and market penetration.

- Due to the size of their fruit, vegetable, and ornamentals industries, the University of Florida and the Texas A&M University have the strongest research, education, and extension programs in horticultural crops.

- The University of the Virgin Islands and the University of Puerto Rico at Mayaguez have considerable strength in the area of production problems but limited expertise in the postharvest handling, transportation, and marketing fields. Both universities, as well as the University of Florida, have been involved in research in the Caribbean Basin region through the CBAG program since 1974, although very limited joint research has been focused on the marketing of horticultural crops.

- The USDA facilities in South Miami (Homestead) and Mayaguez have extensive research capabilities in production and plant protection with little or no capabilities in postharvest problems.

Another important area reviewed concerned the links between national research institutions within and between countries and the relationships between universities throughout the Caribbean Basin region. The University of Florida has by far the strongest link with Central American and Caribbean research and education institutions, addressing the multiple common problems of horticultural crops. However, all states abutting the Gulf of Mexico have some cooperative research, education, and training programs with institutions in the CBI countries.

Overall, there are many research, extension, and educational institutions in the CBI countries and the U.S. states abutting the Gulf of Mexico. However, with respect to successful development of horticultural crop industries, the study found that:

- The three priority common problems--production constraints, plant protection, and harvesting/postharvest technology and management--are not being addressed adequately by public research and education institutions in the CBI countries.

- The limited research and education on horticultural crops underway in the CBI countries primarily is carried out by the private sector; however, much of the technology deriving from this research is proprietary and not widely disseminated.

- The public sector research/education institutions that are becoming involved in research on horticultural crops often are not effectively linked with existing private sector agricultural research on horticultural crops.

- Overall, across the three Basin sub-regions, there is very little coordination of research and education on horticultural crops.

- Generally, CBI and U.S. horticultural crop producers do not have an effective forum for discussing and setting research priorities or for disseminating the results of research to horticultural producers.

In view of the growing markets for horticultural crops, these three common problems should receive greater attention in terms of joint research and education. However, over the long run, establishment of research priorities needs to be a dynamic, interactive process between technology users and technology suppliers.

In short, <u>there is a need for improved links and communication between technology suppliers and users in a way that facilitates research on problems of common concern</u>. This can be stimulated by a mechanism that (1) ensures systematic dialogue between public and private research and educational institutions; (2) strengthens the role of the private sector in establishing research priorities and in providing research funding support; and (3) facilitates technology transfer to horticultural producers through education, extension, and other means as appropriate.

Given the differences in the scale of operation between CBI and U.S. producers of tropical and sub-tropical horticultural crops, care needs to be taken that any mechanism to facilitate joint research and education on common problems leads to shared benefits.

SECTION IV

POTENTIAL BENEFITS OF JOINT RESEARCH AND EDUCATION

A. Need for Joint Research

Most Caribbean and Central American nations are small and find it difficult to support comprehensive programs in agricultural research and education. This situation is even more marked in the islands of the Caribbean, where even fewer nations than in Central America are sufficiently large to support more than minimal agricultural research and education programs. In both Central America and the Caribbean, regional institutions such as CATIE and CARDI, respectively, have evolved to assist the nations within each of these two regions in developing agricultural research and education programs. Despite the presence of such regional institutions, many gaps still exist in the capacities of CBI countries to do the research and education essential for supporting development of horticultural crop industries.

Generally, joint research allows for specialization, thereby reducing duplication as well as research costs, a factor that is a concern to U.S. as well as CBI producers. Specifically, for U.S. producers, implementing agricultural research on a joint basis makes it possible to conduct research year round, thereby reducing the amount of time needed to generate results.

A report on "Agricultural Research in the Caribbean" (Trigo, 1988), published by IICA's Technology Generation and Transfer Program, points to the benefits of a cooperative coordinating mechanism for strengthening agricultural research and education programs of a group of countries. Some coordination systems (networks) have been created through donor support in concert with countries in a region, although these networks are aimed primarily at supporting/developing research on traditional food crops.

The implication for strengthening research and education on problems of common concern to Caribbean Basin producers is that strong consideration needs to be given to facilitating the coordination of collaborative or joint research and education on horticultural crops. There is reason to believe that much progress has already been made in this sphere for traditional food crops, but comparable initiatives for horticultural crops are lacking.

B. Potential Benefits of Joint Research

While quantitative data on the exact magnitude of economic benefits of joint research and education could not be developed within the time frame provided for this study, past research on

returns to investment in agricultural research suggests that the potential economic benefits to CBI and U.S. horticultural producers of joint research and education on problems could be very large. Supporting data are provided in annex 10. The limited data available from various economic analyses indicate that further research and education on horticultural crops are desirable and that the payoff to such investment in research and education would be high, with a higher return than development efforts in many other sectors.

As an example, a recent study (Ansoanuur, 1988) on returns to postharvest research and development in the winter tomato industry found that postharvest expenditures have a very high rate of return, with growers and distributors receiving 33 percent of the returns and consumers 67 percent. For every additional dollar of pre-harvest research investments, the societal surplus increased by $10.85. For postharvest research investments, the societal return was $12.70 for each additional dollar of investment. The net average rates of return showed a similar pattern of distribution. On average, society received $348 for research investments made prior to harvest; postharvest research returns were greater.

As the United States faces the future, Secretary of Agriculture Yeutter is emphasizing competitiveness as the strength of U.S. agriculture. In testimony before Congress on the 1990 farm bill, he noted that research, education, and technology are the means to maintain competitiveness. Frank Press, as president of the National Academy of Sciences, stated that scientific exploration has intrinsic cultural and intellectual values of the deepest kind and that it deserves support on these grounds. "However," he said, "the large resources allocated by governments and industries to scientific research find their justification on the more pragmatic grounds of national economic and political security."

Support for additional agricultural research on horticultural crops will, on the basis of the available evidence, contribute to the expanded agricultural development and welfare of all three sub-regions of the Caribbean Basin. With this in mind, the following section highlights examples of potential economic benefits that CBI and U.S. horticultural industries could receive from a joint program of research and education on the problems identified as common to Caribbean Basin and U.S. producers of horticultural crops.

1. Plant Protection

Basic knowledge developed on identification, characterization, epidemiology, and control of pests and diseases (particularly viruses) would be beneficial to the CBI countries and the U.S. Southeast. Improved knowledge of the distribution of specific pests and diseases in Central America and the

Caribbean would assist efforts to exclude them from the United States, thereby protecting existing agricultural industries.

Eradication of fruit flies from a given country would have the benefit of eliminating crop losses and would result in the relaxation of export constraints on countries that restrict products from fruit fly areas. Economic losses to Guatemalan growers of mango, orange, pear, and peach due to fruit flies were estimated at $7.5 million in 1987.

There is a dearth of research on accurate estimates of crop loss data. Joint research on possible non-chemical control methods has universal applicability. Parasitic or predatory organisms native to one region may be found and used in biological control programs for other regions. Agriculture in the U.S. Southeast could benefit greatly from research on biological control in the CBI countries. Many of the important horticultural pests have been introduced or are annual immigrants from the tropics. Further introductions are also a constant threat. It is a well-established principle that such pests are subject to a wider range of biotic control agents in their geographic areas of origin than in areas where they are introduced.

Further research is needed to determine the pathways and the biology of the migration of pest species. Such research, which will provide the knowledge needed to understand how pest population dynamics in the tropics affect the U.S. pest problem, is essential before complete management systems can be developed. Joint research of scientists in CBI countries and the U.S. Southeast would expedite solving many pressing entomological and pathological problems.

2. Harvesting/Postharvest Technology and Management

Joint benefits of research and education in determining optimal harvest maturity stages would provide for stronger year-round markets. Superior product taste and quality can be achieved only by harvesting at the ideal development stage. Maturity indices need to be defined (i.e., soluble solids, starch content, acidity, color) for optimal harvest stage of many crops. Educational efforts are needed to avoid physical injuries from improper picking, handling, and packing procedures.

Postharvest technology is a very problematic area for all horticultural businesses in the Caribbean Basin region, and it is also a major common problem for U.S. growers. In some cases, the optimum storage temperature and humidity conditions have not been clearly established for exotic tropical horticultural products. Joint research between U.S. and Caribbean institutions would benefit industries in both areas. Lack of rapid removal of product field heat results in rapid ripening and deterioration. Thus, product quality and nutritional value are negatively

affected. The optimal method of pre-cooling, whether by forced air, hydrocooling, slush-icing, or vacuum cooling, has not been identified for many of the tropicals. Joint research on mechanical electronic grading systems to maintain uniform product quantity as well as on containers and packaging materials to minimize product bruising would benefit all growers.

Maintaining product quality control is often lacking in packinghouses because personnel are not trained. In many CBI countries, quality considerations are of little importance in domestic food marketing systems. This not due to the lack of appreciation of good quality produce; rather the economic benefits for applying high grades and standards are not evident. Changing the inadequate grading practices of indigenous laborers hired to work in export packing sheds is a difficult managerial challenge. Compliance with improved standards of quality and more rigorous grading procedures requires continuous education and supervision of the labor force.

Certain tropical commodities should not be stored below 12 to 15°C, in order to prevent physiological damage due to chilling injury. Joint research on the postharvest physiology and biochemistry of tropical commodities will provide an understanding of the exact storage requirements for each crop and the consequences in loss of quality and marketability suffered if growers do not adhere to optimum postharvest conditions. Certain commodities are very sensitive and adversely affected by ethylene gas, a natural ripening hormone. Joint research on individual commodity sensitivities would benefit mixed load shipments from both the United States and the Caribbean Basin countries.

Many subtropical and tropical horticultural products cannot be exported because of fruit fly quarantine restrictions. Joint research on identification of the optimal plant quarantine treatment methods to satisfy the phytosanitary requirements of importing countries would benefit Caribbean Basin growers who export to the United States during the domestic off-season and U.S. growers exporting to Pacific Basin countries.

Strategies for postharvest pest and disease control should employ an integrated preventive approach, including sanitation, postharvest chemical treatments, modified atmosphere packaging, and management of such improvements in commodity system.

3. Production Constraints

Many growers need assistance with land use, terracing, soil conservation, fertilization requirements, mulching, and planting of cover crops. Joint research in these areas would be beneficial to all producers. Prevention of soil erosion preserves the global ecosystem. Improved technology from joint research on the fate of nitrogen fertilizers in different soil

types would allow for better fertilizer management and protection of ground water from nitrate contamination, a serious hazard to human health.

Two of the most limiting factors on crop production for U.S. growers are iradequate fertility practices and improper irrigation practices. Research on identification of proper fertilizer placement, rate, and timing for each individual crop and/or variety would benefit growers throughout the Caribbean Basin region. Many growers currently use too little or too much fertilizer and suffer yield losses. Salt burn is a common problem resulting from fertilizer misapplication; and buildup of soil salinity is becoming more serious as growers in the United States have restrictive water utilization rights.

Research is needed on water use rates of horticultural crops under different environmental conditions. Establishing the threshold moisture levels at which yield or quality reductions occur in each crop could help all growers decide if the expense of irrigation justifies the benefit. Research also is needed on the optimal and most economical irrigation methods for specialty crops produced both in the United States and in CBI countries.

Public consciousness of chemical use by the farming community has been elevated in recent years. Production without chemicals is difficult, but not necessarily impossible. Research to establish the proper crop rotation sequence or intercropping systems to minimize weed and pest pressure would benefit all horticultural growers; little research has been done on this.

Utilization of different mulches (organic, plastic, paper) may result in higher fruit and vegetable crop yields due to more uniform soil moisture retention, weed control, and sanitation against soil-borne disease. Further research and development of this technology may result in preservation of soil structure, minimal soil erosion, and better crop yield and quality. Photodegradable mulches offer a potential solution to environmental waste and need to be researched under many different microenvironments to establish the optimal type to use in each region. Use of mulches for fruit and vegetable growing is beneficial to yield and quality. Research in this area would be beneficial to growers in both the CBI countries and the United States.

Manipulation of the production cycle of a plant will allow products to be available during the market windows. Research on plant growth regulators and their effect on the flowering/ fruiting processes would provide for more year-round product availability. Frost protection research is needed to extend marketing periods. Utilization of plastics for this purpose offers great potential, but research in this area is in its infancy.

With the ever-changing availability of agricultural chemicals, research on identifying the optimal plant spacing, population density, and plant growth habit would benefit both CBI and U.S. growers. Research on production practices for producing optimal economic yields also would be beneficial.

SECTION V

IMPLEMENTING JOINT RESEARCH AND EDUCATION

A. Five Options Considered

There is a need for improved coordination of research and education on horticultural crops in the Caribbean Basin region. Improved coordination can be achieved by establishing a collaborative network that would provide opportunity for involvement of public as well as private actors in research and education on horticultural crops. What mechanism could provide an effective means to support joint research and education on the common problems identified? Table 3 identifies five options.

Table 3. Five Options Concerning Support for Joint Research and Education on Identified Priority Common Problems.

No Intervention Option--Agricultural research and education in the Caribbean Basin continue to function as is without any intervention.

Option A--Establishment of a collaborative research and education center as a new organization.

Option B--Establishment of a collaborative research and education center as a new organizational unit in an existing institution.

Option C--Strengthening research and education programs of and networking among existing, largely public, institutions, with funding provided directly to the institutions and the private sector playing an advisory role in how these funds are allocated.

Option D--Implementing a private joint research and education program coordinated by an international horticultural industry group, with funding provided directly to this group which, in turn, would allocate funding to the institutions.

Each option was evaluated in terms of staffing pattern, coordination, likely impact, and cost, although information availability and time restrictions precluded analysis of the specific cost of each option. Given the identified need for joint research and education, the first option, little or no intervention was ruled out. Options A and B provide for the creation of a new organization or a new unit within an existing organization, respectively, while Option C focuses on strengthening research and education programs of existing organizations, the majority of which at both the national and

regional levels are public institutions. Some of the relevant points regarding these options are now considered.

Significant cost limitations are associated with establishing a new research and education center (option A). Indeed, horticultural producers throughout the Caribbean Basin region were fully in agreement that no new agricultural research or education centers should be established. They feel that existing research and education institutions should become more responsive to the problems horticultural producers are facing.

While establishing a new organizational unit in an existing research and education center (option B) would be less costly than establishing a research and education center as a new organization, the apparent need is for getting existing research and educational organizations to collaborate more effectively; there was no apparent reason to believe that establishment of a new research and education center within an existing organization would be the most effective means of responding to this need.

Option C focuses directly on the question of improving the coordination of research and education among existing, largely public, institutions, proposing sub-regional coordinating roles for a designated institution within each sub-region (e.g., CATIE in Central America) and an overall or regional coordinating role for IICA. However, the private sector's role in this option is largely advisory, with little if any direct control over setting research priorities, allocating research funds, or disseminating research results. Further, implementation of this option could be impeded by inertia, all of these research, education, and technical assistance institutions basically being public sector organizations that simply cannot respond as quickly or as flexibly as the private sector.

A further consideration is that horticultural producers in the Caribbean Basin region, but particularly in the U.S. Southeast (e.g., Florida), have expressed a desire to form a private non-profit association that would facilitate the producers in:

- Establishing an agenda for research and education on the common problems faced by horticultural producers in the Caribbean Basin region;

- Communicating this agenda to agricultural research and education institutions in the region; and

- Translating research findings into practice through improved dissemination of findings and technologies developed through research.

In light of these considerations, option D provides for the research funding to be channelled through a research and

education program coordinated by a private international horticultural industry group, thereby linking technology users in the private sector and researchers in the public and private sector, with the private sector having direct control over the setting of research priorities, allocation of research funds, and dissemination of research results. At the same time, by providing support for agricultural research, this option serves to strengthen and to improve coordination of public sector research and education on horticultural crops. To the extent that it would be desirable, this option also could provide a means for the private sector to play a greater role in funding research on horticultural crops.

B. Conclusion

While the scope of work for this study did not provide for a systematic review of horticultural crop research underway in the private sector in the Caribbean Basin region, the report provides sufficient information to conclude that option D, that of establishing a private coordinating body, comprising Caribbean Basin horticultural producers and mandated to fund and coordinate joint research and education among existing Caribbean Basin research and education institutions, would provide an effective means for implementing joint research and education on common problems facing horticultural producers in the Caribbean Basin region.

Further, the report recognizes that a systematic review and analysis of private sector horticultural research could provide an important input to making a final decision about the most appropriate approach for investment aimed at facilitating joint research on the common problems facing CBI and U.S. horticultural producers. However, the reader should bear in mind that data on private investment in agricultural research are very difficult to obtain even in the United States.

The following section considers the functions, sustainability, and expected impact of option D.

1. Functions

This option would establish a private, non-profit horticultural industry group (or association) composed of the growers, packers, processors, shippers, transporters, and importers in the international horticultural market, including the growers and exporters of horticultural crops in the Caribbean Basin region. The association's work would be assisted by a Research and Education Advisory Council (REAC) composed of representatives of Caribbean Basin agricultural research and education institutions.

As conceived by the producers, the association's mandate would be to assist horticultural producers in the Caribbean Basin region in developing domestic and export markets for horticultural crops,

including fruits, vegetables, and ornamentals. This mandate would include setting priorities for the funding, coordination, and dissemination of the results of joint research on common problems facing the horticultural industry in the Caribbean Basin region. This program would be implemented through a series of competitively-let research contracts.

The association would have as its prime objectives, (1) evaluation of common problems facing horticultural industries in the Caribbean Basin region; and (2) support of research, technology transfer, and other activities designed to solve priority problems and disseminate research results (e.g., technology) to industry participants, including growers, packers, processors, shippers, transporters, and importers. The association, supported by member participation and assisted by the Research and Education Advisory Council (REAC), would:

- o Identify and prioritize common problems that need to be addressed through joint research and education;
- o Circulate a research needs agenda soliciting proposals from public and private research organizations to carry out research on the agenda's priority common problems;
- o Review the research proposals submitted and fund the proposals selected;
- o Monitor research implementation and review the reports submitted by the contracted researchers; and
- o Disseminate research findings, conclusions, and recommendations among association members throughout the Caribbean Basin region.

The association would work with a range of participants in tropical fruit, vegetable, and ornamental industries to support development of tropical horticultural markets through:

- o Industry representation, promotion, and market development;
- o Industry negotiation with the Environmental Protection Agency (EPA), USDA (APHIS), U.S. customs, and other governmental regulatory organizations;
- o Business development (fostering joint ventures);
- o Identification of priority common problems for research and development; and management of funding for industry-wide research;
- o Collection and dissemination of production and marketing statistics on the horticultural industry; and

- Publication of a newsletter reporting industry news, statistics, and association-sponsored research.

2. Sustainability

Funding support could come from a mix of sources, including member associations and commercial firms in the private sector (multinationals, ocean freight companies). Initially, start-up funding for a pilot program (e.g., five years) would need to be provided by interested donors. Based on favorable evaluation of the program, additional funding could be provided on a matching grant basis during the program's next five years (years 6-10). During the program's sixth year, donor funding could match 80 percent of the research funds privately raised by the association, with matching grants during years 7 to 10 declining as follows:

Year	Percentage Matched
7th	60
8th	45
9th	30
10th	15

Donor funding during program years 6 to 10 could be made contingent on the association having put into place a mechanism for developing the organization's self-sufficiency. In other words, by a designated target date (e.g., program year 3), the association would implement a program (a check-off system) whereby growers would be assessed a determined per-box amount (e.g., US$.01) on each box of produce sold in the marketplace. The monies generated would be used to create a fund to support the association's research program. Thus, disbursement of matching grant funds would facilitate development of a self-sustaining mechanism to finance ongoing research and education on the common problems most affecting horticultural crops in the region.

If this mechanism proved, during its start-up period, to be beneficial to the development of the tropical fruit, vegetable, and ornamental industries in the Caribbean Basin region, as evaluated by these industries and donors, then additional funding for support of the program would be expected from the private sector. The level and eventual termination date of donor funding would be phased according to a predetermined time schedule. Evaluations of the program would be done every two years, with required adjustments made on the basis of the experience gained.

3. Expected Impact

The proposed mechanism would not only have a strong impact on the nations within the Caribbean Basin region, including U.S. growers and market participants. Implementation

of option D also should result in highly improved research and education competence within the research institutions that participate in the development of research and education programs supported by the association. Researchers in CBI countries would be afforded the opportunity to cooperate with U.S. researchers in developing solutions to problems and to interact and exchange information with U.S. research and education specialists participating in the program.

Of course, U.S. researchers would benefit from collaborating with specialists throughout the Caribbean Basin region. Overall, this mechanism should greatly facilitate exchange of market-relevant technology and information in the region. Thus, links between CBI and U.S. technology development and transfer institutions could be improved without creating another new research center or institute.

The requirement in option D that research proposals provide for joint collaboration of research and education institutions in CBI countries and the U.S. Southeast would facilitate exchange of technological information throughout the region. While extension services in the United States are generally effective in disseminating the results of research, public extension services in Central America and the Caribbean have yet to reach peak effectiveness. Option D would strengthen the ability of the private sector throughout the Caribbean Basin region to disseminate research findings to market participants, including growers, thereby complementing technology transfer by public extension services.

C. Some Additional Considerations

In the long run, linking option D with a donor-funded network of public research, education, and technical assistance organizations would provide an additional impetus to technology generation and transfer across the Caribbean Basin's three sub-regions. However, this would require ongoing reorientation of the research priorities and approaches of public sector organizations toward an increased emphasis on research geared to the production constraints on and market opportunities for horticultural crops. In the short run, the implementation of option C would serve to begin this reorientation process within the public sector.

Given current difficulties in sustaining funding for public sector research and education institutions in the Caribbean Basin region, option D would enable the private sector in the region to quickly mount a systematic and coordinated research and education program on common problems facing horticultural growers in the region. With this mechanism in place, donor agencies (WB, IADB, CDB, A.I.D., etc.) could effectively target funding support for developing tropical horticultural crops throughout the region. Improved research and education on common problems constraining

market development of these crops would increase the range of production and marketing options for all agricultural producers, including those who are primarily or solely subsistence farmers. Indeed, the potential positive impact that developing horticultural crop markets could have on the income-earning potential of subsistence farmers points to the need for donors to allocate more resources to the cultivation of this opportunity.1/

In the final analysis, the private sector plays and should continue to play a lead role in developing horticultural crop industries, especially in the case of horticultural crops in the CBI countries. Virtually all the plant protection, postharvest handling, and production technology for horticultural crops such as melons, berries, winter vegetables, and asparagus has been adapted by the private sector through on-farm research. These are the same major problems identified in this study as the priority common problems facing Caribbean Basin producers. While some research can be done by the private sector, especially where a profit can be made, there is a need for additional research on horticultural crops that can be achieved only by greater involvement of and participation by the public sector, especially in basic or applied research and the collection of generic data.

1/von Braun, Hotchiss, and Immink, Nontraditional Export Crops in Guatemala: Effects on Production, Income, and Nutrition, Research Report 73, IFPRI, Washington, D.C.

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APPENDIX

OVERVIEW OF RESEARCH AND EDUCATION INSTITUTIONS IN THE CARIBBEAN BASIN REGION

Annex 7 of the JAREF Study Technical Report provides the research mandate and detailed information on Caribbean Basin research and educational institutions involved in research and/or education on non-traditional agricultural export (NTAE) crops. This appendix briefly familiarizes the reader with the names and acronyms of these institutions. Also provided are acronyms of major A.I.D.-assisted projects and institutions working on NTAE crop development in the region. Other organizations working at the national level in the region not reviewed here include FAO, bilateral technical assistance projects of other governments, and various non-government organizations (NGOs).

A. The Caribbean

The principal sub-regional agricultural research institution in the English-speaking Caribbean is the Caribbean Agricultural Research and Development Institute (CARDI), with headquarters at University Campus, St. Augustine, Trinidad, and research staff and facilities on each of the Caribbean islands. CARDI primarily has focused on basic food crops but in recent years has begun to place increased emphasis on research on NTAE crops. The Faculty of Agriculture of The University of West Indies (UWI), also in St. Augustine, Trinidad, is the main degree-granting educational institution in the English-speaking Caribbean.

The Caribbean Agricultural Trading Company (CATCO), based in Barbados, seeks to increase food commodity trade among CARICOM member states and in extra-regional markets. CATCO is a mixed public/private stock corporation, with 51 percent of its stock held by the Caribbean Food Corporation--a regional organization owned by the 12 CARICOM governments. The Caribbean Industrial Research Institute (CARIRI), in Trinidad, conducts research and development on food technology (e.g., food processing). WINBAN, an umbrella organization for Windward Islands banana producers associations, has developed into a model research and extension organization in the Caribbean.

U.S.A.I.D.'s Eastern Caribbean Mission (RDO/C) is implementing the West Indies Tropical Produce Support (TROPRO) project to provide market information, production, and postharvest handling support for NTAE crop development in OECS countries. Under TROPRO, CARDI will have primary responsibility for research, CATCO for extension. The Inter-American Institute for Cooperation on Agriculture (IICA) (see section III.A.1) has a project, "Strengthening Farmer Organizations in the Windward Islands and Antigua and Barbuda," that seeks to improve the quality of production and marketing services reaching the members of farmer organizations.

Other organizations involved in research and education on NTAE crops in this sub-region include the Agricultural Development Foundation (ADF) and the Superior Institute of Agriculture (ISA) in the Dominican Republic and the Jamaica Agricultural Development Foundation (JADF) in Jamaica.

B. Central America

The Tropical Agricultural Research and Training Center (CATIE), Turrialba, Costa Rica, is an autonomous regional institution devoted to research and education for agricultural development and integrated management of natural resources in CATIE's seven member countries--the Dominican Republic and six Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama). CATIE, like CARDI in the Caribbean, has focused primarily on basic food crops but in recent years has begun to place increased emphasis on research on NTAE crops. While CATIE's research mandate is limited to the organization's member countries, CATIE has a Latin American mandate in education (M.S. and continuing education levels).

The Fundación Hondureña de Investigación Agrícola (Honduran Agricultural Research Foundation) (FHIA), in La Lima, Honduras, is a private nonprofit research organization that was created to foster expansion and improvement of technology generation and transfer to meet production needs and export opportunities of Honduran farmers. The Escuela Agrícola Panamericana (Pan American Agricultural School) (EAP), El Zamorano, Honduras, is a private, nonprofit, degree-granting agricultural college.

The Escuela de Agricultura de la Región Tropical Húmeda (Agricultural School for the Humid Tropics) (EARTH), located in Costa Rica, is a four-year agricultural university that will focus primarily on agricultural education for the humid tropics. The school opened for its first class of students in March 1990.

The Federación de Asociaciones de Productores y Exportadores Agropecuarios y Agroindustriales de Honduras (now FPX, formerly FEPROEXAAH), San Pedro Sula, Honduras, is a private agricultural export development organization that provides growers/exporters of tropical fruits, vegetables, and ornamentals with assistance in identifying export projects, developing financial packages for financing, and assisting exporters in postharvest handling, transportation, and export marketing.

The Consejo Agropecuario Agroindustrial Privado (CAAP), San Jose, Costa Rica, is a private organization that seeks to develop a sustainable horticultural crop export industry and to improve product quality to exportable standards. CAAP assists NTAE crop growers in production, pest management, postharvest handling, and marketing. CAAP provides funds to the University of Costa Rica (UCR) for production and processing research on NTAE crops.

The U.S.A.I.D./ROCAP Non-Traditional Agricultural Export Support Project (PROEXAG), in Guatemala City, Guatemala, is working to create and/or strengthen private sector capabilities through the provision of "hands-on" training and technical skills related to production technologies and market intelligence for NTAE crops. PROEXAG assists export federations in four Central American coun-tries (CAAP in Costa Rica, FUSADES in El Salvador, Gremial in Guatemala, and FPX in Honduras) in strengthening their capacity to export non-traditional crops. Assistance is provided in all aspects of production, pest management, postharvest handling, transportation, and market penetration.

The Inter-American Institute for Cooperation on Agriculture (IICA), in San José, Costa Rica, is an international organization for technical cooperation and strengthening of institutions in its 31 member states, including the United States and countries of Latin America and the Caribbean. IICA has five programs, including technology generation and transfer and marketing, the latter including an NTAE component.

C. U.S. States Abutting the Gulf of Mexico

The Caribbean Basin Advisory Group (CBAG) was funded by Congress in 1974 for research on tropical and subtropical agriculture by the University of Florida (UF), the University of Puerto Rico (UPR) at Mayaguez, and the University of the Virgin Islands (UVI). Administered by the USDA, CBAG focuses on two objectives: (1) obtaining readily useful information that will improve production and marketing of agricultural commodities produced in the Caribbean and broaden their research base; and (2) providing information to the United States on critical agricultural problems unique to the semi-tropical area of the U.S. Southeast.

CBAG offers graduate student and post-doctoral level training of Caribbean Basin students at UF, UPR, and UVI. Cooperation on research projects also is given by the USDA subtropical and tropical research stations in Homestead, Florida and Mayaguez, Puerto Rico. The following crops have been identified for high priority research: aroids (root crops such as taro), papaya, and tropical vegetables (sweet potato, potato, tomato). Research emphases include regional testing of tropical fruit cultivars, yams, peppers, and sweet potatoes; pest management; water management; soil and crop management technology; postharvest technology for the tropics; plant stress; insect migration patterns; food processing; and technology transfer improvement.

In 1989, the total budget allocated to research was $1.56 million, with about 55 percent of the grants allocated to the University of Florida, 30 percent to the University of Puerto Rico, and 15 percent to the University of the Virgin Islands. The average grant size was $37,000 for 41 funded projects.

The Animal and Plant Health Inspection Service (APHIS) of USDA is supporting pest surveys throughout the Caribbean to monitor population levels of insects potentially damaging to the commercial U.S. industry. By cooperating with foreign governments, APHIS strengthens plant protection and quarantine activities for pests of concern to the United States. APHIS has cooperated with IICA and the USDA in surveying Grenada and St. Vincent, declaring these islands free of fruit flies, and allowing fruit to enter the United States from these markets without quarantine restrictions.

The USDA Horticultural Research Laboratory, in Orlando, Florida, conducts research on bacterial, fungal, nematode, and virus diseases of citrus and sub-tropical fruits. Areas of research include development of rapid, practical, and economical methods of pathogen identification, disease characterization, biological control of diseases, and characterization of host-parasite interactions and epidemiology. Postharvest research includes developing technologies for increasing shelf life and maintaining quality and condition by environmental manipulation and improved handling methods; and assisting in development of effective, non-toxic quarantine treatments for commodities in the domestic and export markets.

The Tropical Agriculture Research Station (TARS), Mayaguez, Puerto Rico, is part of the South Atlantic Region, Agricultural Research Service, USDA. TARS conducts tropical agricultural research for the benefit of the United States, Puerto Rico, and other countries of the Caribbean Basin by introducing, evaluating, selecting, multiplying, preserving, and distributing germplasm; developing systems to increase food production for local use and export; and developing systems for long-term use, conservation, and management of tropical plants and soils.

The University of Puerto Rico (UPR), Mayaguez, Puerto Rico, is a U.S. Land Grant university. The College of Agriculture conducts extensive research on tropical fruit and vegetable crops within Puerto Rico's various departments. The university also has six Agricultural Experiment Stations located in distinct regions of the island. This provides coverage of various soils and climatic zones representative of the Caribbean. Basic laboratory research is supplemented by applied field production research. The UPR offers undergraduate, graduate, and short-term training in all aspects of NTAE crop production, storage, food technology, and marketing. The campus is physically adjacent to the USDA's TARS, where a number of cooperative research projects are conducted. UPR has excellent cooperative ties with the University of Florida and the University of the Virgin Islands.

The University of the Virgin Islands (UVI), St. Croix, Virgin UPR is a member of CBAG. Islands, is a publicly-supported Land Grant university that offers programs of instruction, research, and public service on NTAE crops. A baccalaureate program is

offered in agriculture, with courses in farm management, tropical agriculture, and food preservation. UVI is a member of CBAG.

The Institute of Food and Agricultural Sciences (IFAS) of The University of Florida (UF), Gainesville, Florida, conducts research, teaching, and dissemination of science-based information through the extension service. IFAS research supports Florida's $US 40-billion food, agricultural, and natural resources industries; prepares students for careers in those industries; and delivers technology to consumers on a wide variety of topics.

The Center for Tropical Agriculture (CTA) is a component of IFAS. CTA supports academic departments and faculty in developing tropically oriented courses and degree programs; coordinates interdisciplinary research projects; and plans and arranges administrative, academic, and technical support for domestic and international activities related to tropical agriculture. The Center offers special training programs in agriculture at the UF campus and at Agricultural Research and Education Centers located throughout Florida. The Center is also involved in research in collaboration with Caribbean research and education institutions such as the Pan American School of Agriculture (EAP) in Honduras.

IFAS also operates the Tropical Research and Education Center (TREC) at Homestead, Florida. This unit has 17 faculty positions in entomology, plant pathology, genetics, tissue culture, and fruit and vegetable horticulture. Most of TREC's research is commodity-oriented, including but not limited to winter vegetables (tomato, bean, potato, squash, etc.), boniato, yucca, melanga, calabaza, tropical fruits (lime, avocado, mango, annona, carambola, papaya), and sugar cane.

For at least 20 years, scientists at TREC have cooperated with scientists in the Caribbean including personnel at CARDI, CATIE, IICA, and EAP. Cooperative studies with scientists in the Dominican Republic, Puerto Rico, and the French Islands are in progress. For several years TREC scientists have been recipients of grants addressing Caribbean research problems under the CBAG program of Special Grants administered by USDA/CSRS.

The Food and Resource Economics Department (FRED), a part of IFAS, is developing the International Agricultural Trade and Policy Center (IATPC), which is aimed at expanding Florida's comparative advantage in tropical and subtropical agriculture on a resource-sustaining basis. Specific attention will be directed to improving the U.S. agricultural trade position generally and to Florida's competitive position in domestic and foreign markets for agricultural products and services.

FRED has been involved, under a USDA/CBAG grant (1987-90) in a study called "Intra-Caribbean and U.S. Agricultural Trade:

Implications for Development." During 1988-89, the department carried out a study on the Latin American/Caribbean Debt Crisis Effects on Aggregate Trade Flows and Florida Agriculture. As a follow-up to these studies, the department is projecting funding under CBAG for studies on the Caribbean Basin Debt Crisis, Agricultural Trade, and Agricultural Diversification; and Economic Feasibility of Producing Specialty Crops in the Caribbean Basin.

The Louisiana State University (LSU), Baton Rouge, Louisiana, is a Land Grant university. LSU's College of Agriculture conducts research on NTAE crops in the areas of breeding, plant protection, crop production, postharvest technology, processing technology, and marketing. LSU engages in cooperative research with the USDA, FHIA (in Honduras), and the UPR (in Puerto Rico), primarily in the areas of pest management and germplasm development for vegetable crops. LSU has strong links to Jamaica in developing a new agricultural university. LSU offers undergraduate and graduate degrees in all aspects of fruit and vegetable crops, including plant breeding, crop production, pest management, food processing, and marketing. LSU is recognized as a leading pest management research center.

The Texas A&M University (TAMU), College Station, Texas, offers undergraduate and graduate training in many aspects of horticultural crops (breeding, crop production, pest management, marketing, and food technology). Research is conducted on crop improvement, plant protection, food processing, and marketing. Cooperative research programs exist between TAMU faculty and the private sector within Texas and Mexico. TAMU has cooperative projects with FHIA on melon virus control research and with USDA-TARS, Mayaguez, Puerto Rico, on starchy root crop genetics.