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REDUCING COSTS AND INCREASING EFFICIENCY OF NATIONAL CROP PROTECTION PROGRAMS IN GRENADA

Final Report

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For:

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AND
ENVIRONMENTAL PROTECTION
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Preface

This report was developed as part of the Consortium for International Crop Protection's (CICP) agreement (PIO/T NO. 543-0005-3-40157) with USAID/Grenada's "Grenada Agricultural Sector Revitalization" (AID Project No. 543-0005). Work of CICP was made possible through a "buy-in" arrangement between USAID/Grenada and CICP's "Integrated Pest Management and Environmental Protection Project" (AID Contract No. DAN-4142-C-00-5122-00, Project No. 936-4142, AID/S&T/AGR). Through the buy-in, CICP provided a range of technical services in pest and pesticide management during 1986. CICP personnel in charge of the work and their schedules in Grenada are shown in Appendix 1.

The report analyzes the pest and pesticide problems in Grenada and suggests ways for reducing costs and increasing efficiency of crop protection efforts. It is based on interviews with farmers, personnel of commodity organizations, Extension, and other organizations listed in the report, and references appearing at the end of the report. A number of CICP personnel contributed in gathering the data and writing the report.

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Executive Director
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INTRODUCTION

Agriculture is essential to Grenada's economy. In 1985, exports of cocoa, banana, and nutmeg were estimated at EC $46.3 million. Exports of fresh vegetables, fruits, and food crops were estimated at EC $13.3 million. Agricultural production accounts for some 40% of export earnings, and the agricultural sector employs more than 20% of the labor force.

Produced on approximately 4,047 hectares (10,000 acres), cocoa is the major export crop. The annual harvest is valued at EC $12 million. Bananas, produced on 809 hectares (2,000 acres), are also a major source of export earnings. Increased vegetable production is a high priority. Efforts are underway to decrease vegetable imports, promote home use, and develop export markets. Approximately 2,900 metric tons of vegetables and root crops were produced in 1983.

However, an examination of trends in production levels and costs raises serious questions about Grenada's ability to sustain and improve agriculture. Agriculture and agribusiness have stagnated, and income from the major export crops has declined.

For example, although Grenadian cocoa has a yield potential of 1,000 kg/ha, present yields average only 500 kg/ha on larger estates and 125 kg/ha on small subsistence farms. The present yields in fact are no greater than yields of the early 1900's despite today's much higher production costs.

Banana production has declined 10% since 1978. The present yield average of 10 t/ha is less than half of what should be

possible.

PRESENT HIGH PEST LOSSES AND INEFFECTIVE CROP PROTECTION

A range of technological, economic, institutional, and social factors constrain Grenada's agricultural sector. Pests--insects, plant pathogens, nematodes, weeds, and other harmful organisms--and inefficient and costly programs to combat them are among the important constraints.

Specialists estimate that uncontrolled cocoa pests cause yield losses of 20-30%. To counter losses, the Grenada Cocoa Association (CGA) and Cocoa Rehabilitation Project (CRP) invest more than EC $2 million per year to control the pests.

The Grenada Banana Cooperative Society (GBCS) spends EC $900,000 for fungicide applications against banana leaf spot. Banana growers additionally spend EC $500,000 or more in weed and insect control. Twenty-two field surveyors are employed and equipped to eradicate the threat of Moko disease of banana.

Although there are no estimates of pest losses to vegetables, the losses to such crops as tomatoes and cabbage are high and control measures expensive. Tomato and cabbage farmers sometimes apply four or more pesticide applications per year and still suffer pest losses.

Despite the large annual investment in crop protection, pest losses remain high, and, in fact appear, to be increasing according to some estimates. The use of pesticides is intensive in some crops, highly ineffective, and may cause harm to human health and the environment. Pesticide applications are usually

scheduled around calendar dates rather than on economic criteria and may therefore be unnecessary or applied at the wrong time. The pesticide applicators rarely wear protective clothing or follow safe practices and sometimes report feeling sick after applying the materials. Heavy use of pesticides in bananas, cocoa, and some vegetables raises questions about their impact on the environment.

INSTITUTIONAL OBSTACLES

CICP personnel identified the following primary institutional obstacles slowing progress in the development and implementation of economically efficient, safe, and environmentally sound crop protection in Grenada:

* Lack of coordination among government agencies and commodity organizations
* Lack of research in crop protection
* Lack of farmer participation in the crop protection programs
* Lack of pesticide monitoring and safety education programs

Poor Coordination

Poor coordination, communication, and information dissemination between government agencies and commodity organizations is a serious obstacle. Farmers told CICP personnel that they are often unsure which agencies they should contact when pest problems arise. Even Extension and commodity

organization personnel are sometimes unsure of the boundaries separating responsibilities of the various organizations engaged in crop protection. The problem is compounded by the multi-cropping systems that characterize Grenada.

A number of organizations may engage in crop protection on a given multi-cropped farm (i.e., CRP in new plantings of cocoa, GCA in established cocoa plantings, GBCS in banana). Farmers are dissatisfied and sometimes confused by the duplication, omissions, and even conflicting recommendations from the different sources.

Poor coordination also hampers effectiveness of pest control operations currently run by GBCS, GCA, CRP, and the Moko project. The duplication of manpower, equipment, and material resources is inefficient and unnecessarily costly. Undue emphasis is placed on the unilateral use of pesticides. There is minimal emphasis on educating and training farmers on use of the less expensive and often more effective nonchemical control methods. Nationally, there is one pesticide applicator per 100 farmers but only one Extension worker per 250-600 farmers.

Lack of Research

Lack of research emphasis on pests and pest management techniques is another significant constraint. Pest management strategies cannot be developed without adequate knowledge of pest life cycles, techniques for monitoring pest levels, relation in pest numbers and damage caused, and effectiveness of various

control measures.

None of the Ministry of Agriculture (MOA) agencies are conducting research related to crop protection. Both based in Grenada, the Caribbean Agricultural Research and Development Institute (CARDI) and Inter-American Institute for Cooperation on Agriculture (IICA), are potentially important research resources. However, they presently have minor programs in crop protection.

Lack of Farmer Participation

The present system of subsidized crop protection, administered by GCA, CRP, and GBCS, prevents farmer participation in pest control decision making and discourages them from using effective cultural practices. Presently, expenses are paid out of a general pool of funds collected from all farmers. Farmers choosing to use cultural practices known to reduce pest incidence still have to pay the same amount of money for pest control services as the farmers neglecting these practices.

Many of the pest problems, especially in cocoa, could be reduced by cultural practices such as pruning and sanitation. However, as long as crop protection is subsidized, farmers now neglecting these practices will probably continue to neglect them. The presently low market prices add further to this neglect.

Farmer input is also minimal in the area of planning and

directing policies affecting agriculture. Farmers interviewed by CICP personnel expressed dissatisfaction in the commodity programs and commodity board check-off fees, and some were displeased with cocoa varieties provided by CRP.

Health and Environmental Concerns

Heavy pesticide use in cocoa, bananas, and some vegetables raises concern about contamination of ground water, residues on food crops, and ecological upsets. There are presently no programs to monitor pesticide use, contamination and residues, or human health effects, and pesticide safety education seems to have had a minimal impact.

BENEFITS OF NATIONALLY COORDINATED EFFORT

A nationally coordinated effort in crop protection would reduce pest losses; increase farmer yields and profits; eliminate much of the unnecessary pesticide use, associated costs, and risks to humans and the environment; and encourage farmers to execute good pest control practices. Part of the savings accrued could be diverted into programs to train and assist farmers in carrying out pest control practices. Increased use of monitoring techniques and cultural practices would reduce use of pesticides, slow the development of pest resistance to pesticides, and reduce health and environmental risks. By consolidating and centrally coordinating crop protection under one organization, there would be less duplication of effort and costs of labor and equipment

(sprayers, vehicles, etc.) would be reduced. Labor no longer required to apply the pesticides could be utilized in educational and monitoring programs. This approach has a potential of increasing yield 20% and reducing pest control costs 30-50%, according to estimates provided by crop and pest specialists interviewed.

NEEDED INSTITUTIONAL CHANGES

The following institutional changes are recommended:

* Designate MOA as lead agency for all crop protection activities
* Increase farmer participation in the crop protection efforts
* Improve farmer training and education
* Support research essential in improving crop protection
* Improve extension-research cooperation
* Improve information base

Designating MOA as Lead Agency

The Ministry of Agriculture is the natural lead agency for maintaining effective national coordination of crop protection activities. Input from CGA, GBCS, CRP, farmers, CARDI, IICA, and others could be provided by an advisory committee. The advisory committee would establish priorities for research, extension, and crop protection operations.

Educational services and training programs in crop protection should be placed under the MOA's Extension Service.

Commodity organizations should concentrate their efforts on purchasing, processing, storing, and marketing the crops and providing financial services to growers as needed.

The Pest Management Unit (PMU) is a potentially important coordinating body, but the following factors presently constrain its effectiveness: (1) lack of a full-time director, (2) small and relatively inexperienced staff, and (3) heavy demands of the fruit-fly trapping project.

Increasing Participation of Farmers

Appropriate changes should be made to phase out much of the present subsidized pest control and increase the farmers' overall participation in crop protection. Some pest control operations (i.e., aerial applications for banana leaf spot) are beyond the farmers' capabilities. However, properly trained and provided with technical assistance, farmers could carry out many of the pest control operations now routinely done by the commodity organizations.

A program that charged farmers a fee for the amount of pesticide actually used, or provided a rebate if no pesticide was needed, would encourage the farmers to use good management practices known important in reducing pest severity. The program could be implemented gradually in conjunction with a strong educational program that emphasized use of good management practices.

Improving Farmer Training and Education

Farmer training and education in pest and pesticide management should be a high priority. The traditional mid-day meetings of Extension programs are presently limited because of the high off-farm employment and the Extension officers' and farmers' lack of transportation. Therefore, other techniques are needed.

Radio broadcasts offer an inexpensive and effective way to reach large audiences. Some farmers interviewed by CICP personnel said they regularly listened to radio programs offered by the Grenada Banana Cooperative Society. If broadened to include all crops, and broadcast at times determined by survey to be most widely utilized by farmers, radio programs should have a positive impact. Programs could include pest alerts, information on monitoring, selecting control strategies, as well as announcements of upcoming meetings.

Simple posters similar to the CRP poster on the value of shading cocoa should be encouraged. Posting information in highly visible places acts as a frequent reminder of the importance of good management.

Short publications written specifically for farmers on topics such as proper pruning techniques, identification of pests, sprayer calibration, pesticide selection, etc., should also be encouraged. Extension offices should stock a complete selection of the publications for distribution to farmers.

The Peace Corps might assist in these efforts. The

Volunteers have been effective in developing farmer educational materials in some countries.

Farmer meetings either in the classroom or the field offer opportunities for detailed instruction and discussion of crop protection problems. Meetings should be announced well in advance by radio and newspaper and should be scheduled to conflict as little as possible with off-farm jobs. Offering training after work near employment sites might be a means of reaching more farmers.

Demonstrations offer another means of disseminating information. Often farmers may hear about new ideas, but be uncertain of their usefulness. Actually seeing how new techniques compare to old ones or how a certain procedure is done can be a powerful means of changing attitudes.

Increasing Research Support

Applied research, conducted mostly on farmers' fields, is essential to any effort aimed at reducing pesticides and increasing use of nonchemical control methods. Some of the pest problems (e.g., the wetwood termite in cocoa) are unique to Grenada and can be solved only through research conducted locally.

The research capabilities of CARDI and IICA should be utilized. However, a local initiative under the direction of MOA is needed to address critical areas of applied research. The researchers should posses at least a B.S. degree in a discipline

geared toward agricultural production and/or protection (agronomy, horticulture, entomology, pathology, weed sc: nematology, animal science). Both degree training at th university level and short-term ("retread") training in areas of pest and pesticide management should be encoura

Important research needs include the following:

* Development of monitoring techniques, economic thresholds, and decision-making guidelines for pr pests of cocoa, bananas, and vegetables
* Evaluation of crop varieties for disease and inse resistance as well as yield and quality
* Weed control practices for newly established plan cocoa and bananas
* Optimal frequency of weeding and pest species interactions with each other and environment, i.e. nematodes vs. weeds, predators and parasites, etc.
* Shade requirements (shade species and proper amoun shade) for cocoa at various elevations
* Use of alternatives to herbicides (e.g., stale see technique, mulches)
* Ways to eradicate Moko through use of disease-free plants, and methods of transmission of the Moko ag
* Study of the socio-economic factors affecting farm acceptance of various crop protection practices

Improving Extension-Research Cooperation

All agricultural education services and training programs should be coordinated by the MOA Extension Service. Commodity organization personnel successfully carrying out education programs should be offered comparable positions in MOA.

The education and experience levels of all Extension personnel should be upgraded. As a minimum, new officers should have two years of training at the Mirabeau Agricultural Training School (MATS) and additional credit should be given for further education, communication skills, and farm work experience. Salaries, benefits, working conditions, and opportunities for promotion should be sufficient to encourage long-term careers in Extension.

MOA should provide resources (vehicles or full financial reimbursement) required of Extension personnel when carrying out and traveling to meetings, demonstrations, and farm visits.

In-service training related to new developments in pest and pesticide management, technology transfer, and new communication techniques should be routinely offered to Extension officers.

Effective coordination between research and Extension is essential in ensuring the flow of information in both directions. Extension workers can identify information gaps for research to address, while researchers can provide Extension with information on recent findings. Joint Extension-research appointments may one means of ensuring coordination.

Improving Information Base

An improved library and reference system is essential in upgrading research and Extension. MATS and/or MOA would be appropriate locations for collections. The library should be available for in-house use to all persons involved in agriculture. In addition, each Extension office should maintain copies of relevant reference materials for Extension officers' use. A complete set of leaflets and publications describing cultural practices, pest identification, and control should be developed for grower distribution and training.

GUIDELINES FOR PEST MANAGEMENT IN COCOA

The single greatest need in crop protection in Grenada is to reduce pest losses and pesticide use in cocoa. Based on interviews with farmers and personnel of CGA, CRP, and Extension, the appropriate management solutions for the major cocoa pests are as follows. Implementation of the management practices would significantly reduce losses, increase yields, and cut use of pesticides.

Pests and Needed Management Practices

Cocoa beetle: increases with dry weather (< 24 cm rainfall/year), lower elevations(< 61 meters), exposed (unshaded) conditions, nutrient deficiency, and mechanical injury to bark

Solutions: increase shade, canopy, and fertility; care in reducing pruning and harvesting damage; and developing

trapping and monitoring techniques

Thrips: increase with physiological stress resulting from factors such as poor nutrient status and insufficient shade
Solutions: improve shade and nutrient status

Termites: increase with stand age, poor management, improper pruning, and improper weed management
Solutions: proper pruning; perhaps selective use of insecticides

Witches' Broom: increases with high elevation (> 1,000' meters), high rainfall, low temperature, thick shade as from nutmeg, poor sanitation (has worsened since elimination of government removal program), and susceptible varieties (farmers report that the high yielding varieties number 26 and 29 are much more susceptible than traditional varieties)
Solutions: on infected plants remove 15 cm below lesion and burn infected parts to reduce inoculum; fungicide sprays may be effective; select and distribute resistant varieties (number 33 and 70 may have promise)

Black Pod: increases with high humidity, wet growing seasons, and poor management; varieties 26, 29, 36, and 46 are susceptible
Solutions: remove inoculum; fungicide use might be

effective at certain times; select resistant varieties; and encourage good management practices (fertility and pruning)

Weeds: during first years of establishment after clear-felling, weeds cause greatest problems and require control to reduce competition and promote growth of young cocoa. Once a cocoa canopy is formed weed growth should be entirely suppressed and weed control confined to breaks in the canopy caused by insect pests, diseases, or mechanical injury.

Solutions: the first task after planting will be weeding. Young cocoa can be weeded by slashing, usually along the tree rows to a width of 1.0-1.5 m, sometimes circle weeding around the plants to a radius of 1.0 m. Weeds are generally slashed at a height of about 5 cm and the cut vegetation left around the young cocoa to suppress further weed growth and to act as a mulch. Frequency of weeding depends on rate of weed growth. Herbicides may be used to supplement the above practices but should not displace them.

PEST MANAGEMENT DEMONSTRATIONS

Experience with many crops in many different parts of the world has shown that demonstrations of pest management carried out on representative farms is the best way to encourage farmer acceptance.

MOA Extension personnel in conjunction with representatives from commodity organizations, PMU, farmers, and research

personnel should determine which practices to demonstrate. Selection should be based upon several factors: (1) importance of the practice to good crop production, (2) availability of back-up research or technical assistance to support the practice, (3) current lack of implementation of the practice by good farmers, and (4) practical feasibility in setting up the demonstration.

Care should be taken not to set up demonstrations that exceed the economic means of the farmers. The demonstration sites should be located on the farms of farmers that their peers recognize as leaders, and they should be easily accessible by road and bus routes. Farmers included in the demonstrations should not, however, be of significantly different educational or economic status of the surrounding farms. The model farms project being promoted in Grenada may be utilized for some demonstrations, but not all. Farmers not involved in the model farms project may be reluctant to participate in or accept information derived from the project.

Duration of the demonstrations will depend on a number of factors. Demonstrations of pest sampling and pesticide application techniques, for example, would be carried out only during a given farmer meeting. Other demonstrations would require a continuing effort and must enlist long-term cooperation from the participating farmer. Long-term demonstrations would also require substantial input from technical resources, an advisor to give guidelines, and possibly additional labor. Long-term demonstrations would include weed control methods during

establishment, effects of shade vs. no shade on various pests, optimal fertility practices, or effects of cultural practices on disease and insect development.

Good management practices all fit together in a cohesive system and can be demonstrated as a unified package. However, the system may have to be adopted, piece by piece, over a long period of time until the farmer has sufficient experience and confidence in its application. Since some farmers may not be able to implement all phases of a pest management package on their own land simultaneously because of resource constraints, etc., the demonstration should emphasize the most important practices, but also identify secondary ones.

The demonstrations could be set up so as to demonstrate the following:

* Advantages of good weed control during establishment of a new crop in achieving rapid growth, earlier production, and higher yield
* Use of shielded sprayers for non-selective herbicides
* Value of proper pruning techniques
* Value of shade
* Value of windbreaks
* Nematode damage under different cultural practices
* Value of fertility
* Variety selection based on resistance, quality, marketability, and adaptability to variations in elevation and moisture

* Value of crop rotation
* Value of seed treatments
* Value of sprayer calibration
* Value of pesticide safety
* Trapping and monitoring techniques for pests
* Value of sanitation practices in management of black pod and witches' broom (removal of infected plant parts and sterilization of implements could be included in the demonstrations)

Evaluation of demonstrations should consider the proportions of growers made aware of the practice; which farmers have adopted the new practice; which have not adopted the practice and why they have not done so; changes in income, yield, labor, pest incidence, and pesticide use; and any other changes in farm practices or status as a result of adoption.

The demonstration sites should be used as focal points for meetings with farmers. They can also be used as training sites for new Extension officers and as a source of information for researchers planning new projects.

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APPENDIX 1

CICP Personnel and Schedules in Grenada

Name	Dates in Grenada (1986)
Dale Bottrell University of Maryland	2/25-3/3; 6/1-8; 8/13-30; 11/18-22; 3/4-11 (scheduled for 1987)
Galen Dively University of Maryland	6/16-30; 11/10-19
Joseph Knapp University of Florida	8/15-9/11
Betty Marose University of Maryland	8/15-30
Marshal McGlamery University of Illinois	6/1-30
Myron Shenk Oregon State University/ International Plant Protection Center	6/1-8; 8/15-30; 11/2-21

STUDIES OF THE BIOLOGY AND MANAGEMENT OF THE COCOA BEETLE AND WET WOOD TERMITES - MAJOR PESTS OF COCOA IN GRENADA

Research Preproposal

Submitted by the
Consortium for International Crop Protection (CICP)
University of Maryland, College Park, MD, 20742

INTRODUCTION

Cocoa is the major export crop in Grenada where ca. 11,850 acres are grown, primarliy intercropped with bananas, mangoes, nutmeg, and coconuts. The annual yield of 5.5 million pounds of beans is valued at EC$12 million. Cocoa production has stagnated during the past decade because of many institutional, technological and socio-economical factors. Present yields are not much higher than yields of the early 1900s. A major constraint is the estimated 20 to 30 percent loss in yield caused by pests.

The cocoa beetle, Steirastoma breve, and wet wood termites (Neotermes spp.) are among the most important pests of cocoa in Grenada, respectively ranked first and third in severity (personal communciations, USAID/CICP sponsored pest management training workshop, Mirabeau, Grenada, August 1986). Both insects cause wood-boring damage which frequently leads to death of the trees. Infestations have become more prevalent since the late 1970's as a result of suboptimal management practices and shade reduction. One cocoa expert reported that the cocoa beetle population in Grenada is the highest observed in any cocoa production area (personal communciation, E. Imle, Pan-American Development Fund).

Damage by cocoa beetles and termites can be reduced significantly by applying a combination of the following cultural measures: (1) shade and windbreaks in both established and rehabilitated cocoa fields to reduce physiological stress and to alter the microclimate unfavorable to pests; (2) proper drainage and fertility practices to enhance general crop vigor and productivity, thus making the crop more tolerant to pests; (3) structural and maintenance pruning of the trees to ensure proper canopy formation; and (4) routine pruning of dead or wounded branches that attract beetles and termites.

These cultural practices are seldom employed in full because many farmers are too old to do the work and cannot find good labor. Furthermore, many small farms and even large estates are poorly managed or abandoned because the owners are part-time or absentee farmers. These farms jeopardize the benefits of cultural practices applied on neighboring farms by acting as a reservoir for pests.

Chemical control directed at wet wood termites is limited to local applications of insecticide and/or diesel fuel to infested sections of branches during routine pruning activities. The problem with this approach is the time required to treat and the fact that termite colonies often cause extensive damage before being discovered, since no nests or covered runways are constructed.

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Cocoa farmers generally do not apply chemical control for the cocoa beetle. Instead, they are assessed a fee at the point of sale, which goes to the Grenada Cocoa Association (GCA) for pest control services. In addition, the Grenada Cocoa Rehabilitation Project (GCRP) administers chemical control programs on newly established cocoa fields. These organized programs are expensive, have led to an overuse of chemicals, and are largely ineffective because of limited information on actual pest population levels, faulty spray application, and poor timing (most treatments are applied too late).

The ecological disruptions associated with the indiscriminate use of pesticides applied to intercropped systems of cocoa are well known. In addition, pesticides can be hazardous to humans, particularly in Grenada where few people are properly trained in pesticide application and safety. Therefore, during the past few years, the policy of the Grenada Ministry of Agriculture in cooperation with the various cocoa groups has been to concentrate on the development of an integrated pest management approach to cocoa pest problems, involving a combination of cultural practices, biological controls and a more efficient use of pesticides.

The adoption of pest management practices for the cocoa beetle and wet wood termites will require research support. The most immediate needs lie in the areas of pest biology and behavior, pest monitoring and prediction, pesticide management and the development of alternative control tactics. The following research studies are proposed because of their likelihood to reduce pest losses and improve pesticide effectiveness in a relatively short period of time.

PROPOSED STUDIES

A. STUDIES OF THE AGGREGATION PHEROMONES AND HOST-PRODUCED ATTACTANTS OF THE COCOA BEETLE, AS A PREREQUISITE FOR THE DEVELOPMENT OF METHODS FOR MONITORING AND MASS-TRAPPING ADULTS.

A timely assessment of flight activity of the cocoa beetle is of utmost importance in preventing economic losses in cocoa fields. Effective control can be achieved by applying insecticides during a 3 to 4 week period of peak adult activity at the beginning of the rainy season. Various trapping techniques using pieces of freshly cut wood of *Pachira insignis* (Chataigne maron, a preferred wild host) have been employed for monitoring and also as a control measure (Fennah 1948). Their use has been limited because of the time involved in estabishing the traps and the lack of information regarding their effectiveness.

At the present time, the GCA and GCRP conduct only cursory surveys in areas with a previous history of beetle activity. Spray decisions are based on visual searches of old damage, pressures from influential farmers requesting control action, and past experiences of the supervisor in charge. One or more applications of insecticides are usually applied in the most infested areas during February, March and April when adult activity is highest. This approach frequently leads to poorly timed sprays and an overuse of chemicals because trees that have been repeatedly attacked tend to become less attractive as they get older. Thus, adult activity may not be high enough to cause further economic loss, even though old injury is evident. Furthermore, many newly established fields become infested for the first time but are not treated. A practical monitoring method is needed to detect early flight activity so that

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timely control action can be taken in fields where insecticide treatment is most warranted.

The ease with which beetles locate wood of the wild host and fresh wounds in cocoa trees suggest that strong chemical cues are involved, perhaps involving host odors reinforced by the release of aggregation pheromones after the beetles find a suitable food source. Aggregation pheromones are known to occur in six insect orders, but the majority have been studied in the Coleoptera, particularly the bark and timber beetles (Scolytidae) (Borden 1985). Host selection and aggregation of bark beetles are usually induced by a complex of attractants, including one or more host monoterpenes (host odors) and one or more beetle-produced compounds that may have a differential effect depending on concentration.

Aggregation pheromones of bark beetles have been utilized for surveys (McLean and Borden 1975; Mclean 1980), for containing infestations (Kopf and Pitman 1971; Ringold et al 1975; Dyer 1975; Borden et al. 1983), and for mass trapping (Bedard and Wood 1981; Lanier 1981; Lie and Bakke 1981; Lindgren and Borden 1983). A number of commercially produced pheromone lures are currently available and used routinely in the management of major forest pests, such as ambrosia beetles and the mountain pine beetle. If pheromones or other chemical attractants were available for the cocoa beetle, more effective monitoring and control programs might be feasible.

Capture, extraction and bioassay of volatile stimuli - The first phase of this study will involve the extraction and testing of all possible attractants of the cocoa beetle (Objective A.1). Large numbers of newly emerged cocoa beetles will be collected by using *Pachira* trap branches and visual search techniques in areas with high infestations in Grenada.

As described by Garcia and Mendes (1986), adults will be reared in screened cages containing cocoa tree seedlings as a substrate for oviposition and feeding. Larvae will be reared in plastic containers on the artificial diet of Hensley and Hammond (1968) used for the sugarcane borer.

Volatiles from beetles, frass and the host plants will be captured on Porapak Q or Penex substrate and extracted for bioassay. Large numbers of beetles of mixed age and sex will be field collected and aerated in chambers with the collecting substrate. A blank aeration will be performed in the same way but without beetles. Volatiles from frass and from pieces of infested and uninfested cocoa and *Pachira* branches will be obtained as described for beetles. The concentration of volatiles collected during aeration will be expressed quantitatively in terms of beetle hours or gram hours of frass or host plant material. Volatiles will be extracted from the collecting substrate with purified pentane and distilled to concentrates for bioassay.

An open arena, airflow olfactometer described by Borden et al. (1979) will be used to determine if the odors of cocoa beetle populations of different sizes and sexes are attractive to beetles of either or both sexes. Air passed over frass and cut branches of the infested and uninfested host plants also will be tested for attractiveness. A two-choice, pitfall olfactometer will be employed to test the response of the cocoa beetle to volatile concentrates versus a solvent control (Pierce et al. 1981). Each experimental stimulus and concentration of a test extract will be replicated using fresh beetles. Results will be expressed as the mean percent response of the total number of

beetles per treatment.

Fractionation, identification and synthesis of suspect attractants - The second phase of the study is designed to identify, synthesize and produce candidate attractants for field tesing in Grenada (Objective A.2). Because sophisticated analytical methods are used, this phase will be conducted at a chemical ecology laboratory in the U.S or Canada. To provide adult beetles for bioassay testing, a colony of cocoa beetles will be established from infested cocoa branches from Grenada and maintained on potted cocoa seedlings grown in the greenhouse. Adults and larvae will be reared in large numbers as described above.

Volatile concentrates that are found to be attractive to cocoa beetles will be fractionated using a series of gas-liquid chromatographic methods (GLC). All fractions will be bioassayed alone and combined, along with the pentane solvent controls, so as to disclose active single- or multiple-component attractants. All bioassays of fractions will be done in an open arena, airflow olfactometer using fresh adults of the same age and density. Since cocoa beetle adults have relatively large antennae, another technique using electroantennograms (EAG) may be used to determine biological activity of volatiles, thus possibly eliminating some steps in the purification procedure.

Fractions with the highest biological activity will be identified through mass spectra (MS) and nuclear magnetic resonance spectra (NMR) studies. Identified compounds will be synthesized and bioassayed for attractiveness. Also, bioassays will be conducted to test the attractiveness of fractionated compounds versus their synthetic counterparts to verify authenticity. Solutions of natural material will be calibrated by gas chromatography against solutions of synthetic material of known concentration to ensure that the same absolute amounts of a pheromone will be assayed. If more than one fraction is involved, combinations of the synthetic materials will be bioassayed against the natural material to determine the best blend of the compounds. Both pitfall and airflow olfactometers will compare biological attractiveness. The most active synthetic materials will be produced in larger quantities and formulated as pheromone lures for field testing in Grenada.

Field testing - This phase of the study will be conducted in Grenada to determine the relative attractiveness of synthetic pheromones (or host attractants) to natural populations of the cocoa beetle and to determine the optimum trap design and pheromone release device (Objective A.3). All field trapping experiments will be conducted in heavily infested cocoa fields during the peak period of beetle activity. Replicated treatment combinations will be set up in a randomized block design, with a minimum distance of 25 meters between traps.

If the laboratory bioassays determine that more than one aggregation pheromone is involved along with host-producing compounds, a series of experiments will be conducted to test each attractant alone and in all possible combinations. The baits will be released from either open glass vials or plastic bottles with holes drilled in the cap, depending on the chemical and release rate required. The multiple funnel trap described by Lindgren (1983) will be used in these tests because it is highly efficient, non-sticky and requires minimum maintenance. This particular trap may be too costly for an extensive survey or mass trapping program in Grenada; however, it should be the best choice for providing a critical evaluation of bait attractiveness.

In other experiments, ranked responses of the cocoa beetle to the most active pheromone or pheromone-attractant combination will be determined for various trap designs, including baited branches, a cylindrical trap coated with Stikem Special (Byrne et al. 1974), the multiple funnel trap (Lindgren 1983), and others. Each trap design will be tested in combination with various pheromone dispensers, including Conrel fibers, plastic bottles, glass vials, and others. The primary purpose of these experiments is to develop a relatively simple, but efficient trapping device that would be operationally and economically feasible in Grenada.

B. STUDIES OF THE APPLICATION OF A PHEROMONE-BASED MANAGEMENT PROGRAM FOR THE SURVEY, CONTAINMENT AND SUPPRESSION OF THE COCOA BEETLE.

Survey of infestations - If a practical and efficient pheromone trapping system is developed, its application as a survey tool has great potential because female cocoa beetles exhibit a long pre-ovipositional period (about 23 days). This allows the pest manager enough time to survey adult beetle activity and apply insecticides before the adults begin to lay eggs. However, a survey trap is limited unless the pest manager is able to use the catch data to predict damaging larval populations.

To determine the relationships between the number of adult cocoa beetles captured and subsequent larval infestations (Objective B.1), pheromone traps will be set up in a grid pattern of one trap per acre in cocoa fields with a wide range of infestations. Prior to adult emergence, visual counts of the number of fresh and old galleries on the trunk and branches up to 40 cm from the jorquette per tree will indicate the infestation pressure from previous generations. Trapping will take place during the first month of beetle activity in February or March. Traps will be replaced weekly and the baits checked, replaced or refilled if necessary. Beetles will be removed and counted. After the trapping period, biweekly visual inspections will determine the average number of fresh galleries and live larvae present per tree. Differences in the number of galleries recorded for the previous generation will express the current generation's attack. Correlations of beetle-larval activity within a generation will be made to establish trap catch levels associated with low, moderate and heavy larval infestations.

Containment of infestations - The current practice of rehabilitating cocoa fields in Grenada involves a gradual phasing out of old trees as new ones are planted (Turrialba method). Although this approach is popular with the farmers, it favors rapid buildup of cocoa beetle populations because adults emerging from the old infested trees can easily find and colonize the young trees. If the pheromone system of the cocoa beetle is more attractive than young cocoa trees, a systematic program of pheromone baiting old trees at the right time may contain the infestation, keeping beetles away from the new trees. Such a management strategy may be more effective during the first few years of rehabilitation than a costly program of insecticide treatments.

To test this hypothesis (Objective B.2), replicates of paired blocks of cocoa trees will be established in rehabilitated fields. The paired blocks will be selected as much as possible for similarities in tree age, spatial distribution of old and new trees, management practices, topographical features, as well as for similar levels of cocoa beetle infestations. The experiment will be set up well before the peak emergence is expected. A grid

pattern will be established in each block, spaced 50 to 100 meters apart. An old tree at or near each grid intersection in the treated blocks will be baited with pheromones. The baiting system will be open or capped vial(s) of the attractants attached to the tree at the jorquette. The concentration and release rates of the dispenser will be determined from previous studies.

In each block, a 100 percent survey of the number of galleries per new tree will be conducted before peak emergence and again after the baiting period when the next larval attack is evident. The position of each baited old tree, as well as each infested new tree will be plotted on a map. A comparison of attack rates and spatial distribution patterns of beetle damage on new trees relative to the baited trees will indicate whether a baiting program can concentrate infestations in old trees specifically designated for cutting before the next generation emerges.

Suppression of infestations - To assess the effectiveness of pheromone traps for suppression of cocoa beetle (Objective B.3), a mass trapping program will be conducted utilizing the most efficient trap design as determined by previous studies. Trapping will be conducted on a grid basis in replicated blocks of cocoa trees compared with similar blocks of cocoa without trapping. Traps will be set up before the beginning of beetle emergence and operated continuously for the duration of the flight periods of two generations. Beetles will be removed and counted each week. Samples of trees will be visually inspected for fresh or old galleries before and after mass trapping. The differences in the change of number of beetles captured and the accumulated damage in the trapped blocks versus the controls will be used to indicate the degree of cocoa beetle suppression.

C. FIELD STUDIES TO DETERMINE THE BEST CHEMICAL, OPTIMUM TIMING, MINIMUM DOSAGE, PLACEMENT AND NUMBER OF INSECTICIDE APPLICATIONS REQUIRED TO REDUCE COCOA BEETLE POPULATIONS.

The current chemical control programs of the GCA and GCRP are directed at the adult beetles and involve 1 to 2 sprays of malathion or fenitrothion (15 to 25 oz per acre) applied to the high risk fields (those with a history of cocoa beetles). Other insecticides (i.e. chlorpyriphos) with longer residual and more penetrating action are available and widely used for control of wood borers in other countries (Brady et al. 1980; Hall et al. 1982; McCambridge 1982; Swezey and Dahlston 1983, Fuchs and Borden 1985). These chemicals may be more costly than those used in Grenada, but if only one spray can achieve effective control of adults and larvae for 4 to 6 weeks, their use may be more economically feasible and present less exposure to workers than current insecticides.

Since an integrated pest management program using pheromone-based traps and insecticides is being considered, field tests will be conducted to evaluate alternative insecticides and minimum effective dosages in comparison with current insecticides (Objective C.1). These tests will include only chemicals affordable to farmers and those that are or could be approved by the Grenada Pesticide Control Board.

Once the pre-oviposition period has passed, adult females begin laying eggs in the bark, preferably at the collar of seedlings, and around the jorquette and wounds of older trees. Selective treatment of these areas may

control the majority of adults and larvae. Another series of field tests will be conducted to determine the minimum effective surface area of the tree to be treated (Objective C.2). This area may depend on tree age, canopy structure and exposure.

Maximum egg laying occurs during the dry season (February, March, April). During this time, adult beetles probably emerge over a period of 4 to 6 weeks, and females usually live for 70 to 90 days. Since the pre-oviposition period lasts about 23 days, insecticide applications may not be necessary until about 3 weeks after the beginning of adult emergence. Since adults cause only minor damage, the best strategy may be to wait until a larger portion of the population has emerged. Assuming the remaining population of adults emerges during the following three weeks, the effective period of adult control is probably about three weeks. After this time, sprays may kill adults but are less effective against eggs and larvae that are already in the bark. A third set of tests will be conducted to determine the optimum timing and the minimum number of applications required to achieve economic control (Objective C.3). These parameters may vary with the dosage and type of insecticide used.

All chemical control tests will be conducted using cocoa trees with high infestations of adults and larvae. A randomized block design will be used with replicate plots of 10 to 20 trees. Pre-treatment assessments of the number of active galleries per tree will be recorded to allow for statistical control of between-plot variability. In tests to evaluate insecticide effectiveness, two sprays will be applied 30 days apart starting 2 to 3 weeks after the first significant flight of adults. A motorized back sprayer will be used to treat only the trunk and main branches above the jorquette of the canopy. In tests to evaluate timing, combination treatments of one, two and three spray regimes will be applied starting 2 to 3 weeks after flight activity at intervals of 15 and 30 days. In tests to evaluate the treatment area, two sprays will be applied 30 days apart to varying sections of the tree.

D. STUDIES OF THE ECOLOGY AND BEHAVIOR OF WET WOOD-TERMITES, AS A PREREQUISITE FOR THE DEVELOPMENT OF CULTURAL AND CHEMICAL CONTROL MEASURES.

Termite attack on older cocoa trees is widespread in Grenada and takes on two general types. Numerous species of damp-wood and dry-wood termites (primarily belonging to the genera Crytotermes, Glyptotermes, Macrotermes, and Microcerotermes) attack dead or dying wood from injury caused by cocoa beetle damage, dieback, or other factors. Colonies of these termites are established either in the dead wood, in aerial nests on the tree, in conspicuous earthen mounds, or in underground colonies with covered runways to reach the wood. The effects of this type of attack can be minimized by routine pruning to remove dead wood and the treatment of cut or damaged surfaces with a dressing until they are callused over. Insecticide treatment is seldom needed if these cultural measures are regularly applied. Furthermore, some studies suggest that the mound-building and ground-dwelling termites have a beneficial effect on the nutrient cycle in the cocoa ecosystem.

The other type of termite attack is caused by wet-wood termites (Neotermes castaneus, N. wagneri and possibly other species) which invade the living wood from initial infestations in wounded or dead tissues and generally spread downwards from the point of entry. Colonies are usually found in flat chambers connected by narrow galleries in the heartwood of the trunk and larger

branches. The nest site sometimes can be identified by a rust colored ooze on the bark around the point of attack, especially during the dry season. Since no nests or runways are constructed outside the tree, damage can be extensive before it is discovered, and weakened branches and whole trees often fall during storms.

Very little information is known about wet wood termites that attack living wood, particularly in cocoa. Investigations of Neotermes spp. infesting teak plantations in Indonesia (Kalshoven 1950, 1953, 1959) provide the only significant source of information on the subject. An understanding of the life history and population dynamics of these termites, especially the factors which govern swarming and colony establishmnet, is needed before an effective control strategy can be developed.

Swarming and flight behavior - Since seasonal temperatures do not vary significantly in Grenada, swarming may be triggered by the onset of the rainy season. An understanding of when swarming occurs and how far alates fly before selecting a nest site may be helpful in the development and timing of cultural practices designed at preventing infestations. Field studies will determine the time and duration of swarming and the characteristics of dispersal (Objective D.1). Periodic sampling of established colonies of different sizes over time will determine the time and duration of alate production relative to the age of the colony. A trapping scheme for capturing dispersing alates at varying distances from marked colonies will provide information on flight behavior.

Selection of nesting site - The condition of the wood is very important to the susceptibility of attack by many termites. The alates of Neotermes species that attack living cocoa trees may be attracted either to the odors of freshly exposed wood (resulting from pruning or storm damage), fermenting sap, or perhaps by substances resulting from fungus infestion. After a suitable site is found, certain thigmotactic responses may be involved, especially if the initial entry is made via cracks and holes, such as those made by the cocoa beetle. A particular substrate surface or holes of a specific size may be needed for successful entrance. Laboratory and field studies will determine the factors involved in the selection and initial entry of a suitable nesting site (Objective D.2). Preference tests will be performed using swarming alates caged over wounds and the ends of broken branches with varying degrees of decomposition and surface structure. The frequency of young colonies associated with specific categories of entrance sites will be determined. A knowledge of the conditions required for initial entry into cocoa trees will be useful in the development of specific pruning practices and wound treatments.

Detection of infestations - A knowledge of the external signs of a nesting site is of utmost importance in detecting infestations before extensive damage occurs. Fields studies will identify any visible characteristics associated with infested trees, such as exundates, discoloration or other physical changes of the infested branch (Objective D.3). Sound amplifying or sonic devices will be used to detect infestations within branches that exhibit wounds or dieback sections as "suspect" entry points. These devices are probably not practical at the farmer level but will allow for rapid diagnosis of 'suspect' branches without injuring the tree. Observations of external symptoms will be made on a large sample of colonies of varying ages during the rainy and dry seasons. Core samples using various devices at varying depths and distances from the expected entry point will be taken on infested branches in order to develop a

practical way to expose galleries for treatment (Objective D.4).

Colony foundation and feeding - Numerous studies have demonstrated successful control of "concealed" infestations of social insects using insecticides and insect growth regulators (IGR). The use of these materials to control termite colonies in cocoa trees will require an understanding of colony foundation and the feeding relationships. The rate and pattern of food transfer and whether all colony members participate in feeding influence the rate of spread of a chemical throughout the colony. Field and laboratory studies will determine the caste structure and the food exchange process (Objective D.5). Data will be obtained by direct observations of behavior and by examination of the gut content of different instars and castes. Food sources and "blank" baits will be inpregnated with dyes or radioactive tracers and exposed to colony members for ingestion.

E. STUDIES DEALING WITH THE DEVELOPMENT AND EVALUATION OF CULTURAL AND CHEMICAL CONTROL MEASURES FOR THE PREVENTION AND CONTROL OF TERMITE INFESTATIONS.

Cultural measures for preventing termite attack on cocoa have been incorporated into routine pruning practices using traditional techniques. The particular way that a branch is pruned, whether the purpose is for removing dead wood or for canopy formation, may affect its susceptibility to termite attack. Field tests will set up to evaluate various pruning and wound treatment measures to prevent initial invasion (Objective E.1).

Corrective treatments with insecticides to control infestations within the dead and/or living wood of cocoa trees is advocated in Grenada. Current recommendations are based on only one field test that demonstrated satisfactory control by spraying the pared infested surface with a mixture of malathion and diesel fuel. The infested branch is usually opened to expose galleries by using a cutlass. Field studies will be conducted to evaluate other insecticides with longer residues and more penetrating action and to develop more efficient methods of applying chemicals to infested sections of branches (Objective E.2). Bait formulations of insecticides and growth regulators also will be tested using various means of placing the material in contact with the termites.

RESOURCES AND DURATION OF PROJECT

The overall management and technical assistance required for the proposed project will be provided by CICP, probably through a "buy-in" arrangement with the Consortium's USAID Project No. 936-4140 (Integrated Pest Management and Environmental Protection). Galen Dively will be the key CICP person to manage and carry out the proposed work. The Pest Management Unit (PMU) of the Ministry of Agriculture in Grenada will support the project by providing technician help, facilities and ground transportation required to conduct research activities. The period of time for project completion will be two years, except for tests outlined in Sections B.2 and B3. The chart below shows the periods of contractual assistance/activity for the two years.

Contractual Assistance/ Activity	Assignment Time Periods ¶-------Year 1---------¶--------Year 2---------¶ J-F-M-A-M-J-J-A-S-O-N-D-J-F-M-A-M-J-J-A-S-O-N-D-
Cocoa Beetle Work	
Galen Dively	XX XX
Natural product chemist	XX XX
Pheromone specialist	XX XX
Graduate research assistant	XXXXXXXX XXXXXXXX
Analytical chemistry work outside Grenada	XXXXXXXXXXXXXXXXXXXX
Termite Work	
Termite specialist	XX XX
Graduate research assistant	XXXXXXXX XXXXXXXX

The pheromone studies outlined in Section A will require contractual assistance from Galen Dively, a natural product chemist and a pheromone specialist. The latter two will be contracted from the chemical ecology laboratory where the analytical work will be conducted. Each scientist will make one visit of 4 weeks each year to Grenada. Additional assistance from a UMCP graduate research assistant will be required for a period of 4 months each year to follow up the experiments. The PMU Laboratory will provide technician help and space for rearing and bioassays. Most of the equipment required for field and laboratory testing will be brought to Grenada.

A contractual arrangement with a chemical ecology laboratory (located outside Grenada) will be required for the analytical chemistry work outlined in Section A. One possible laboratory is the chemical ecology group at Simon Faser University, which has unmatched experience in bark beetle pheromone work and already been contacted by GCRP and asked if they would be willing to work on the project. One funding option is to have the Canadian International Development Agency (CIDA) share in the support of the pheromone studies by funding the analytical chemistry work. Dr. John Borden and his colleagues at Simon Faser are interested and have provided a separate budget for this phase of the project.

Objectives A.1, A.2 and A.3 will be completed after two years and the result will be a pheromone and/or attractant trapping system ready for field testing. Some testing for survey purposes (Objective B.1) will begin the second year and will coincide with the second visit of the pheromone research team. Further studies under Objective B.1 and all tests pertaining to the containment/suppression of cocoa beetle infestations (Objectives B.2 and B.3) will be initiated during the third year. This phase of the proposed work is not covered by the estimated budget request. Using procedures recommended by the research team, PMU and GCA/GCRP personnel will evaluate the trapping system during the third and subsequent years. CICP personnel may be involved if additional funding is made available.

The chemical control work outlined under Section C will take place during both years and coincide with the visits of the pheromone research team. Galen Dively will provide the technical assistance with the help of GCA/GCRP personnel. The same research assistant mentioned above also will be utilized for follow up evaluation of the chemical control tests.

The termite studies will be conducted concurrently with the cocoa beetle work but will involve a different team of researchers. Galen Dively will provide the overall coordination. Laboratory facilities and field study sites will be arranged with the help of PMU and GCA personnel. A CICP consultant specializing in termite biology will be assigned for 2 periods of 4 weeks each to set up the research. Another graduate research assistant will also be needed for two-4 month periods to carry out much of the work. Two years will be required to complete Objectives under Sections D and E. Incorporation of new or improved termite management practices into farmer, GCA or GCRP programs will start the second year and should be fully implemented by the third year.

BUDGET ESTIMATES

Item	Year 1	Year 2
COCOA BEETLE RESEARCH (Field Tests in Grenada)		
Salaries/Fees		
G. Dively - 30 days/yr	$6,000	$6,480
J.H. Borden - 30 days/yr - no charge	—	—
A.C. Oehlschlager - 30 days/yr - no charge	—	—
Graduate Research Assistant - 12 months/yr	9,152	9,518
Fringe Benefits	1,872	1,947
Travel	5,330	5,863
Per Diem Expenses - 30 days X 3/yr	14,850	16,335
Housing Allowance - 4 months/yr	1,466	1,612
Vehicle Rental - 4 months/yr	3,800	4,180
Gasoline	525	577
Shipping Charges	1,000	1,100
Supplies/Publications	2,000	2,200
Total Direct Costs	45,995	49,812
Indirect Costs - (20% CICP)	6,994	7,669
(22% UMCP)	2,425	2,522
TOTAL	$55,414	$60,003
Two-Year TOTAL		$115,417

COCOA BEETLE RESEARCH (Analytical Chemistry Work performed outside Grenada)	
Salaries/Wages	
J.H. Borden - 5% of time/11 months	no charge
A.C. Oehlschlager - 5% of time/11 months	no charge
H.D. Price - 50% of time/11 months	$8,993
Research Assistant - 80 hrs/week/11 months	4,664
Supplies	1,900
Total Direct Costs	15,557
Indirect Costs - 65% of salaries/benefits	8,877
TOTAL	$24,434

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BUDGET ESTIMATES- continued

Item	Year 1	Year 2
TERMITE RESEARCH		
Salaries/Fees		
Termite Consultant - 30 days/yr	$6,000	$6,480
Graduate Research Assistant - 12 months/yr	9,152	9,518
Fringe Benefits	1,872	1,947
Travel	1,940	2,134
Per Diem Expenses - 30 days/yr	4,950	5,445
Housing Allowance - 4 months/yr	1,466	1,612
Vehicle Rental - 4 months/yr	3,800	4,180
Gasoline	525	577
Shipping Charges	500	550
Supplies/Publications	2,000	2,200
Total Direct Costs	32,205	34,643
Indirect Costs - (20% CICP)	4,236	4,636
(22% UMCP)	2,425	2,522
TOTAL	$38,866	$41,801
Two-Year TOTAL		$80,667
OPTION 1 - ENTIRE PROPOSED PROJECT		$220,518
OPTION 2 - COCOA BEETLE RESEACH		$139,851

Funding levels will be less if CIDA shares in the support of the cocoa beetle research.

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