INTERNATIONAL ATOMIC ENERGY AGENCY

Mitigating the Threat of Cactoblastis cactorum to International Agriculture and Ecological Systems and Biodiversity

Report and Recommendations of a Consultants' Group Meeting organized by the Technical Co-operation Department of the IAEA and the Joint FAO/IAEA Division of Nuclear Applications in Food and Agriculture, Vienna, Austria, July 2002.

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CONTENTS

EXECUTIVE SUMMARY

Cactoblastis cactorum has become a serious threat to the high diversity of Opuntia (cactus pear) species throughout the world, both native and cultivated. Its presence in the Caribbean and its rapidly expanding range in the southeastern USA, is an imminent threat to the southwestern USA, Mexico, and Central and South America and eventually to other regions of the world where *Opuntia* cacti are regarded as extremely important plants, especially in arid and semi-arid regions where few plants can be grown. These plants have a valuable role in subsistence and commercial agriculture, in maintaining the ecological balance of unique ecosystems, and in soil conservation and combating desertification. Increasing areas in opuntia cultivation and reliance on food and income from products means that invasion by *C. cactorum* has the potential to impact large regions and thousands of subsistence farmers in Central and South America, the Mediterranean, North Africa and in other countries. This impact would result in serious social and economic problems. Impacts on biodiversity and ecosystems where opuntia are dominant components of the vegetation, including the center of opuntia radiation, Mexico, also loom large. The critical nature of this threat, and timing and scale of the likely response needed, requires immediate action.

A Cactus Moth Consultants Meeting held 15-19 July 2002 reviewed and evaluated the threat of *C. cactorum* to international agriculture and ecological systems and biodiversity. These consultants came to the following conclusions and recommendations: (1) The establishment of *C. cactorum* in cactus-growing areas will be devastating. Irreparable ecological and economical damage as well as irreparable social effects are still to be avoided providing that further spread is curtailed; (2) An immediate containment/eradication programme of *C. cactorum* in the southeastern USA, Cuba and other Caribbean islands and particularly along the leading edge must be launched while the chances of containment and control are still possible; (3) The Sterile Insect Technique (SIT) approach is the most promising eradication tool and a critical element of any containment and eradication programme. Sufficient knowledge is available to launch the programme; (4) The threat of *C. cactorum* is not fully appreciated by decision makers, and therefore, effective national and international awareness and regulatory programmes should be immediately implemented; (5) More research and development is needed to refine and increase efficacy of the control and prevention methods; (6) Although the emphasis may initially focus on Mexico, Cuba, other Caribbean islands and the USA, this does not mean that the threat is less important in other countries. Any effective contingency /eradication programme developed under the proposed project will be available for application in any other country; and (7) A collaborative effort among several countries and all available expertise on *C. cactorum* should be mobilized in this programme; 8) The IAEA is encouraged to approve an interregional Technical Co-operation project for the cycle 2003-2004 to facilitate and support the collaboration among countries immediately and practically at risk to prepare for and establish the capacity to deal with invasions of C. *cactorum* . In Annex 1 the proposed workplan and budget for such a project is presented.

1. PROBLEM DEFINITION

Despite the successful biocontrol of invasive *Opuntia* species by the South American cactus-feeding moth *Cactoblastis cactorum* (Berg) (Lepidoptera; Pyralidae), the moth has now become a serious threat to the high diversity of *Opuntia* species throughout the world, both native and cultivated. It is now present in the southeastern, USA; and areas of Cuba and other Caribbean islands. If the cactus moth further invades the southwestern United States (Texas, Arizona, New Mexico, Nevada, California) and Mexico the effects will be devastating. The imminent spread of *C. cactorum* from Florida or Cuba to southern United States and Mexico has to be prevented before it is too late. In addition, C. *cactorum* is a threat to the many other countries where opuntias are of significant importance.

2. IMPORTANCE OF THE PROBLEM

- **Value of Cactus**

Cactus species (*Opuntia* spp.) are regarded as extremely important plants, especially in arid and semi-arid regions where few plants can be grown. They are a major component of the semi-desert regions of the Caribbean and the Americas and increasingly in other semi-arid regions of the world. Their role in maintaining the ecological balance of this vast territory is immeasurable.

The southwestern USA and Mexico are considered the most important centre of biodiversity for *Opuntia.* Cacti in the genera *Nopalea*, *Consolea*, and *Opuntia* (hereafter Opuntia or Platyopuntia) comprise more than 200 species world wide, of which 114 are present in this area. Native distribution of the platyopuntia extends across the New World, with species in the Caribbean, and throughout the Americas. Narrow endemism is characteristic of this group (Annex 4).

1. Agricultural uses:

a) The establishment of sustainable systems of production based on *Opuntia* spp. may contribute to the food security of populations in agriculturally marginalized areas and to the improvement of the soil.

b) As forage: Since they grow in severely degraded land, opuntia use is important because of their abundance (900,000 has.) in areas where few crops can grow. They also have high palatability, digestibility, and moisture content, reducing the need to supply water to animals.

c) As vegetable: The tender cladodes of certain species are used as a vegetable called "nopalitos". These represent a huge industry, being consumed in fresh and processed form mainly in Mexico and the United States of America. Emerging markets in Peru and Africa and increasing Mexican exports to Europe and Asia, shows an expanded demand in non-traditional markets.

d) As fruit and by-products: They are cultivated in many areas of the world (North and South African, the Americas, and Middle Eastern) for pricky pear fruit production and commercialisation. The potential market for this product is extensive but little exploited. Cultivation of *Opuntia* spp. requires extensive labour, which is an important souce of employment (particularly for women) in developing countries.

e) As cochineal: The cochineal insect (*Dactylopius coccus*) produces Carminic acid, which is a natural red dye accepted by health authorities worldwide. Cochineal constitutes a significant alternative to forage or fruit production because of its profitability and intensive use of labour.

f) Industrialization: The industrialization and commercialisation of opuntia products is expanding into concentrated foods, juices, liquors, semi-processed and processed vegetables, food supplements and the cosmetic industry.

g) Medicinal applications: Research has demonstrated promising results on the use of opuntia products for gastritis; for diabetes due to the reduction of glucose in blood and insuline; for hypercholesterolemia by reducing total cholesterol, LDL cholesterol and triglycerids serum levels; enlarged prostate treatment; and for obesity.

2. Environmental issues

a) The species of the *Opuntia* subgenus have developed phenological, physiological and structural adaptations favourable to their development in arid environments, in which water is the main factor limiting the development of most plant species.

b) *Opuntia* spp. can develop in severely degraded soils, which are inadequate for other crops. *Opuntia* spp. have a great capacity for adaptation and are ideal for responding to global environmental changes. Their rooting characteristics reduce wind and rain erosion, encouraging their growth in degraded areas.

c) *Opuntia* spp. are some of the best plants for the reforestation of arid and semi-arid areas within their native range because they can survive scarce and erratic rainfall and high temperatures.

d) Many species of bird, mammal, reptile, and insect species eat, nest in, or otherwise rely on opuntia species. Further, opuntia have been identified as nurse plants, facilitating the establishment of other plant species by providing a more moderate (cooler, moister) and protected growing environment. Large-scale loss of opuntia where they are the dominant species is likely to be accompanied by shifts in species composition of both the vegetation and animal communities.

- **Pest Features**

Cactoblastis cactorum is one of several cactus-feeding Lepidoptera species of South American origin whose larvae feed gregariously inside opuntia cladodes, consuming most of their contents but leaving the epidermis intact. Damage is restricted to the genus *Opuntia* and only few species show resistance to the cactus moth. The hollowed cladodes, which turn white with age, show typical exudates that the larvae expel through small holes made in the epidermis.

The insect has two well-defined generations in temperate climates. In warmer tropical and sub-tropical zones the generations are less well defined and may be overlapping. Females live for approximately 10 days and oviposition usually starts during the second night. The eggs are stacked in the form of a small stick which looks like a spine. A single female lays two or more egg-sticks totalling about 300 eggs. First instar larvae hatch simultaneously and enter a cladode close to the oviposition site through a single hole. They feed gregariously in colonies varying between 20 and 50 larvae. Later instars are reddish in colour with typical transverse black bands. The larval stage lasts between 5-7 weeks in summer and up to 2-3 months in winter. Larvae seldom leave the protection of a cladode in which they feed except when pupating. Pupation can take place in the soil but the preferred sites are in plant debris not far from the host plant.

Adult moths usually emerge during early evening and mating can take place within the first night. Moths are nocturnal and are reluctant to fly far when there are sufficient host plants available, but with a scarcity of food moths may fly several kilometres. Some evidence also suggests that moths may be carried considerable distances with air currents.

- **Damage Potential**

The dramatic impact of *C. cactorum* on invasive opuntia species in Australia, South Africa and many other countries as a biological control agent, and the damage it causes to commercial cultivations of *O. ficus-indica* in countries where it has been introduced, is convincing evidence of the pest status of the moth on desired opuntia. In South Africa cactus pear growers have to follow a rigorous control programme against the cactus moth in order to stay in production. Entire plantations of *O. ficus-indica* (fruit and fodder) and *O. robusta* (fodder) have been destroyed by *C. cactorum* if neglected for a few seasons. Damage to invaded plants is often exacerbated by secondary bacterial infections that can kill large plants in a single season.

Small plants are extremely vulnerable to *C. cactorum* damage, including seedlings and young plants of *O. ficus-indica* and other commercial species. Damage is slightly less apparent in plants with hard woody stems.

The most serious threats of *C. cactorum*, however, are to the many wild species of *Opuntia* in the Caribbean and Central and North America, particularly in Mexico which has the highest diversity of species. It will be virtually impossible to control or even contain *C. cactorum* once it has naturalized in the wild, which may be the final blow to several endangered opuntia species. *C. cactorum* is particularly damaging to new species with which it has not previously been associated, including many species in Mexico and the USA. Studies done by CONABIO (Mexico) have also shown that there are no climatic restrictions to *C. cactorum* in Mexico and that the areas with a high diversity of native species and large commercial plantations all fall within the ideal climatic parameters of the insect.

The present knowledge of potential hosts of *C. cactorum* suggests that the threat may be limited to the species within the Opuntiae. However, some species in the Cylindropuntiae (known as "chollas") may also be affected.

The threat of *C. cactorum* to other important regions of the world should not be ignored. Countries like Tunisia, Spain, Italy (Sicily), Algeria, Israel etc. have large cultivations of *O. ficus-indica* and the arrival of the cactus moth in these countries could be devastating. The value of cactus to combat desertification and its use on marginal lands is widely recognized and any limitation imposed on such developments may deprive people of an indispensable tool to improve rural livelihood in resource-limited countries.

- **Risk for Future Spread and Damage**

C. cactorum was purposely introduced to many areas in the Old and New World for biological control of invasive opuntias. Subsequent to these introductions, the moth was observed to disperse to other locations. For example, *C. cactorum* was introduced to the island of Hawaii in 1950, but was found on the islands of Lanai, Maui, Oahu, and Molaki by 1954 and on Kaui and Nihau by 1957. If humans were not responsible for that movement, *C. cactorum* was capable of traveling roughly 47 km over water from Hawaii to Maui, and 110 km from Oahu to Kaui. Similarly, *C. cactorum* rapidly dispersed in the Caribbean region to the Bahamas and Cuba. Biogeographic migration of the flora following wind and storm patterns, provide clues to likely movement of *C. cactorum* (e.g., Florida-Cuba, Cuba-Yucatan). Currently, *C. cactorum* in Florida appears to be dispersing northward along the coasts at rates exceeding 50 km/year.

While several authors have attributed presence of *C. cactorum* in locations to which it had not officially been introduced to natural dispersal, the distances moved are not consistent with the 2.5 to 24 km terrestrial dispersal distances observed in Australia and South Africa. Dispersal rates in Florida, where opuntia are sparsely but fairly continuously distributed, suggest that greater distances are possible. These distances may be explained by data from South Africa that demonstrate that dispersal distances are inversely related to prickly pear densities. However, *C. cactorum* has also been documented as a contaminant on horticultural shipments of cacti from the Dominican Republic. Additionally, individuals may have purposely or inadvertently translocated the moth to new locations. Regardless of the explanation of dispersal in specific cases, the evidence of continued spread of this species and increasing international trade in host opuntias, widespread cactus cultivation across continents, increasing exchange of germplasm to support this cultivation, and the enrichment of collection in many botanical gardens indicates that the risk of expanding *C. cactorum* distribution is extremely high. Estimates made for the U.S. and for Mexico indicate an extensive potential range for *C. cactorum*, with limitations imposed by environmental (temperature, photoperiod) conditions rather than host availability. Movement from current locations in the Caribbean and U.S.A. into Mexico seems inevitable unless natural and human-caused dispersal is controlled. Similar risks exist in other locations where opuntias are present.

As discussed above, increasing areas in opuntia cultivation and reliance on food and income from products means that the arrival of *C. cactorum* has the potential to impact large regions and thousands of subsistence farmers in Central and South American, Mediterranean, North African and other countries. This impact would result in serious social and economic problems. Impacts on biodiversity and ecosystems where opuntia are dominant components of the vegetation, including the center of opuntia radiation, Mexico, also loom large. The critical nature of this threat and timing and scale of the likely response needed requires immediate action.

3. POTENTIAL OF APPLYING THE STERILE INSECT TECHNIQUE TO *C. CACTORUM*

Sterile Insect Techique (SIT) progammes have been successful against a number of pest Diptera (including the screwworm fly, *Cochliomyia hominivorax*, tsetse flies, the Mediterranean fruit fly, *Ceratitis capitata* and various other fruit fly pests), and numerous mass rearing facilities have been constructed worldwide to support these programmes. However, compared to dipterans, lepidopterans (moths) generally are more expensive to rear and have a propensity to fly greater distances. Additionally, moths are more radio-resistant than dipterans. As a consequence, the larger dose of radiation required to completely sterilize moths reduces their competitiveness and performance in the field. Nevertheless, two SIT programmes are currently operating against moth pests, namely the pink bollworm programme in the USA, and the codling moth programme in Canada, and both of these have been very successful.

- **Inherited Sterility in Moths**

One approach to reduce the negative effects of radio-resistance in Lepidoptera has been the use of inherited or F1 sterility. F1 sterility was first documented in studies on the codling moth. Subsequently, investigators have reported F1 sterility in many Lepidopteran species of economic importance. Like SIT, F1 sterility involves the mass rearing and release of genetically altered insects to insure that when matings occur in the field, a significant proportion of matings involve a treated, released insect. However, F1 sterility takes advantage of two unique genetic phenomena in Lepidopetera. First, Lepidopteran females generally are much more sensitive to radiation than are males of the same species. This allows the dose of radiation to be adjusted so that the treated females are completely sterile and males are partially sterile. Second, when this partially sterile males mate with fertile females, the radiation-induced deleterious effects are inherited by the F1 generation. As a result, egg hatch is reduced and the resulting F1 offspring are highly sterile and predominantly male. The lower dose of radiation used in F1 sterility increases the quality and competitiveness of the released insects. In addition, because F1 sterile progeny are produced in the field, the release of partially sterile insects offers greater suppressive potential than the release of fully sterile insects and is more compatible with other non-chemical pest control mechanisms or strategies.

Field release of partially sterile insects have demonstrated the potential of using F1 sterility to control many Lepidopterans, including the cabbage lopper, *Trichoplusia ni*, the corn earworm, *Helicoverpa zea*, the gypsy moth, *Lymantria dispar* and the codling moth, *Cydia pomonella.* In addition many studies have shown that F1 sterility can be effective combined with other biological control such as pheromone mating disruption, entomopathogens, host plant resistance and natural enemies. As a result of these studies, F1 sterility is regarded as the most favourable genetic method for most applications against Lepidoptera.

- **Nuclear Component**

Sterilization is accomplished by exposing insects to a specific dose of gamma radiation emitted by radioisotopes (Cobalt 60 or Caesium 137). No other methods are available or appropriate to provide achieve sterilization. Chemosterilants carry a high risk for environmental contamination and pose serious health concerns. Linear accelerators have not shown sufficient applicability and reliability in consistently achieving the desired level of sterility.

Nuclear technology has not only a comparative advantage in sterilizing mass reared insects, but is, at present, the only technology available for this purpose. As every single insect used in SIT activities must be sterilized, irradiation is a central and indispensable part of the total process.

- **Development of Inherited Sterility for *C. cactorum***

Although the cactus moth has been mass reared for use as a biological control agent in the past, use of sterility to control it is still untested in the field. Inherited (F_1) sterility could be a valuable tool to predict and manage the expanding populations of *C. cactorum*.

The use of F_1 sterility for control would be most appropriate for:

1) Elimination of *C. cactorum* from areas of new introductions, or from isolated and/or environmentally sensitive areas.

2) Establishment of a barrier through the release of irradiated moths along the leading edge of the *C. cactorum* geographical range.

3) Provisioning sterile *C. cactorum* to assess the host range and potential geographic distribution.

4) Provisioning sterile *C. cactorum* as hosts in the field to assess its potential natural enemy complex.

Studies on the radiation biology of *C. cactorum* have been carried out at the USDA-ARS laboratory in Tifton, GA., in collaboration with USDA-APHIS in Tallahassee, FL and the Joint FAO/IAEA Division in Vienna. Further collaboration with IAEA could facilitate the involvement of international experts to accelerate the refinement of inherited sterility procedures for this pest. For example, South Africa is probably the best location for rearing and irradiating large numbers of *C. cactorum* for use in an action program in the immediate future. Since parts of the Caribbean have been infested with *C. cactorum* since the 1960's, some of the field testing could also take place there.

4. EFFORTS REQUIRED TO ADDRESS THE PROBLEM

- **Awareness**

The critical risk of *C. cactorum* invasion of the southwestern U.S. and Mexico, with accompanying irreparable ecological, economic, and social effects, must be recognized by the highest authorities (agricultural, environmental, economic) of U.S.A. and Mexico. Similar attention will be needed by government leaders in other countries and regions wherever platyopuntia species are native or agriculturally produced. This effort will require cooperative efforts at a global scale, involving such groups and policies as the Global Invasive Species Programme, Convention on Biodiversity, International Plant Protection Convention, and Convention on International Trade of Endangered Species.

A well-articulated and well-directed educational campaign should be immediately developed. This campaign should be strategically planned to selectively target the different sectors involved:

- Political and administrative (governmental agencies).
- Academic, research, and technical institutions.
- Industrial and commercial agricultural areas.
- Growers, farmers, and ranchers involved in the production chain.
- General public.

Development of media communications, educational, and training materials will be necessary.

- **Regulatory measures**

Well-structured frameworks of mandatory regulatory measures should be prepared for both national and international agreements. The regulations should include actions covering:

- Quarantine
- Phytosanitary certification
- Restrictions on plant movement
- Plant inspections
- Early detection
- Control measures
- Crop destruction

The regulatory measures must be applied by all countries involved to avoid movement of *C. cactorum*. The national authorities of plant protection should regulate the internal transportation of cactus plants or parts thereof and provide "*C. catorum*-free" certification to avoid the movement of *C. cactorum* in any life stage.

Cactoblastis cactorum should be included in lists of quarantine pests in countries exporting or importing opuntia material. The quarantine of *C. cactorum* could be also at the regional, provincial, or state level where distribution of the moth is limited. Monitoring systems are required to delineate quarantine boundaries.

- **Early detection of new infestations**

Deployment of early pest detection systems is essential in locations that are under threat of invasion by *C. cactorum*. By taking early actions to monitor for this pest in areas where infestations are likely, newly established populations can be detected. Control is generally most successful and most cost-effective when deployed while populations are still limited in numbers and distribution, as for Mediterranean fruit flies, screwworms, and other pests. Management efforts can then be mobilized and concentrated in these areas to prevent further population expansion and to implement eradication measures.

Populations of *C. cactorum* have traditionally been detected by visual sampling for damage and for the presence of egg sticks. However, recent tests have demonstrated that traps baited with virgin *C. cactorum* females are very effective at capturing males and have proven invaluable in detecting low population levels. While traps of this nature are powerful, their usefulness is limited by the fragile nature of the female moths, the costs of rearing moths and frequently replacing them in the traps, and the necessity of sterilizing females that are used in traps outside an infested area. Identification of a female-produced pheromone is essential in reducing the costs of deploying traps, and in facilitating the expansion of a monitoring system beyond the range of currently known infestations so that early detection is possible.

- **Prevention of further spread**

Accompanying regulatory and other approaches to prevent spread of *C. cactorum*, considerable value is placed on the development and use of tools to monitor populations. These tools are used to precisely delineate the existing range of insect pests and are used to continuously monitor their movement or the "leading edge" of their population. Monitoring tools most commonly utilized include visual scouting. While this method is effective for confirming the presence of pests through careful investigation of their damage, sparse populations can easily be overlooked. The most effective method of determining the distribution of pests is to develop and deploy semiochemical-baited traps.

Like many Lepidopteran pests, the cactus moth is an excellent candidate for the development of pheromone-baited traps. *Cactoblastis cactorum* males have already been captured in traps baited with virgin females, strongly suggesting that females produce a sex pheromone. However, the attractive component(s) of the pheromone need to be isolated, identified, synthesized, and their behavioural activity confirmed. In addition to female-produced volatiles, the importance of host plant volatiles in the attraction of males and females needs to be investigated.

Pheromone traps can be deployed experimentally, for survey, and in monitoring programs to identify the limits of *C. cactorum* distributions. Once *C. cactorum* populations have been delimited, barriers can be established using SIT to prevent further spread of this pest. The SIT has been used as a barrier to prevent the spread of other lepidopteran pests such as the pink bollworm and codling moth.

- **Control/eradication of current infestations**

Several methods of control have been considered and used for management of *C. cactorum*. These include removing the egg sticks by hand, chemical insecticides, insect pathogens, natural enemies, host plant destruction, and the SIT. In high-density production areas for the cactus pear market, hand removal of egg sticks and insecticides such as carbaryl have been successfully used to control recently emerged (neonate) larvae. Insecticide sprays have not been effective once larvae enter cactus cladodes. The use of systemic insecticides injected into cactus stems has been investigated as a means of protecting ornamental cacti and small populations of endangered cacti, but they provided inadequate control. Because many *Opuntia* species are associated with sensitive ecological areas and occur together with rare and endangered fauna, widespread use of pesticides cannot be recommended. In addition to environmental considerations, the economics of treating large tracts of coastal and desert land with pesticides would be prohibitive. Investigation of insect pathogens has not yet revealed any promising agents. Sex pheromones have been used successfully in mating disruption for some pests where the populations are very low, the host plant density is high, and the plantings are contiguous. However, this approach, while critical for survey and monitoring, would be insufficient for *C. cactorum* because host plant density would be too sparse in the natural areas and the area of infestation would be too large.

Biological control is another tactic that could be used against *C. cactorum*. In its native habitat in South America, several natural enemies have been identified including: *Apanteles alexanderi* (Hymenoptera: Braconidae), *Phyticiplex doddi* and *P. eremnus* (Hymenpotera: Ichneumonidae), *Brachymeria cactoblastis* (Hymenoptera: Chalcididae), and *Epicoronimyia mundelli* (Diptera: Tachinidae). However, biocontrol alone will not prevent the further spread of *C. cactorum* or successfully eradicate the species.

Destruction of heavily attacked host plants has been used on a limited basis in the Florida Keys to reduce the population of *C. cactorum* in an effort to protect a rare and endangered cactus species. However, area-wide use of this tactic would be unrealistic.

Preliminary work with the SIT suggests that it will be the most economically and ecologically acceptable method for use throughout the geographical range of *Opuntia* spp. Preliminary studies on the radiation biology indicate that sterility can be induced with a dose of radiation that should allow for the release of highly competitive moths. In addition, the SIT is the only control method that could be used for eradication or the establishment of barriers to prevent the continued expansion of a *C. cactorum* population.

- **Rapid response / contingency plan for new outbreaks**

Contingency plans for a rapid response to new outbreaks of *C. cactorum* are needed to prevent the establishment of this species in areas where *Opuntia* is native and/or cultivated. The Global Invasive Species Programme recommends that when preventative measures have failed to exclude an invasive pest, eradication is the preferred course of action (published in

"Invasive Alien Species: A Toolkit of Best Prevention and Management Practices"). Therefore, every country or region that would be negatively impacted by an infestation of *C. cactorum* requires an emergency response plan. Components of this plan include quarantine methods for the impacted area and protocols for the immediate implementation of an eradication programme. An awareness campaign, destruction of infested host plants, intensive monitoring through surveys of *Opuntias* and the use of pheromone traps, and implementation of the SIT are integral to this programme.

5. CURRENT STATUS OF ACTIONS AND R&D EFFORTS BEING CONDUCTED BY GOVERNMENT OR OTHER AGENCIES

The following are on-going actions being carried out by Member States:

- Radiation biology (SIT, F_1 sterility) – USA.
- Development of survey and trapping technology – USA.
- Surveys to delimit current distribution of *C. cactorum* in the Caribbean Basin and North America – USA, Cuba.
- Pest management technologies (insecticides, mechanical, host destruction/exclusion) – USA, South Africa, Argentina.
- Host range testing – USA, South Africa.
- Risk assessments and potential impacts of *C. cactorum* on agriculture and biodiversity – Mexico, Cuba, USA.
- Host distribution and bioclimatic modeling of potential geographical range of *C. cactorum* – Mexico.
- Education and awareness activities – Mexico, USA, Cuba.
- Mass rearing and shipment – South Africa.
- Ecological and biological Research– South Africa, Australia, USA.
- Restoration of endemic Opuntia– USA.

6. REQUIRED ROLE OF PLANT PROTECTION AND ENVIRONMENTAL PROTECTION AGENCIES, UNIVERSITIES AND RESEARCH ORGANIZATIONS, NGOS, AND OTHER INTERNATIONAL ORGANIZATIONS.

Reducing the threat of *C. cactorum* to ecological, agricultural, and cultural benefits of Platyopuntiae worldwide will require the independent and co-operative efforts of numerous governmental and private organizations. Because of the critical nature of this threat, some emergency actions have already been initiated and others could be initiated prior to year 2003 when the TC project should start in case it is approved. Necessary activities that would help to solve this problem would be performed through the proposed interregional project as follows:

- Mexico and the U.S. immediately require phytosanitary inspection of all imports and exports of cacti for *C. cactorum*. Infected cacti and larvae or other forms of *C. cactorum* are destroyed. Pathways with high probability of *C. cactorum* movement are identified and either eliminated or regulated to ensure no *C. cactorum* dispersal. Other nations develop similar regulations.

- U.S.D.A. issues an immediate pest alert for Florida, Alabama, Mississippi, Louisiana, Georgia, South Carolina, Arizona, New Mexico, California and Texas and works with state Departments of Agriculture to increase nursery inspections, surveys, and destruction of any detected *C. cactorum*.

- U.S.D.A. immediately places *C. cactorum* on the APHIS Regulated Pest List and continues to develop the capacity for rapid response and control of new infestations and containment or retreat of the leading edge of the invasion.

- In country Departments of Agriculture and Plant Protection work with industries that ship opuntia host material to cooperatively reduce the threat of *C. cactorum* dispersal though those materials.

- CACTUSNET informs members about the threat from *C. cactorum*.

- Pests and Diseases Working Group of CACTUSNET proposes phytosanitary standards for safe movement of opuntia genetic material.

- Respective national institutions work with researchers to develop and implement monitoring protocols that would result in early detection and eradication of *C. cactorum* outbreaks.

- Affected and at risk countries promote regional collaboration, which includes countries likely to be critical “stepping stones” for *C. cactorum* dispersal, and seek technical and financial support from national and international institutions and organizations to develop and implement specific phytosanitary and control methodology to develop barriers that reduce the probability of *C. cactorum* establishment and spread.

- The Nature Conservancy’s Invasive Species Initiative works with the Center for Plant Conservation and other NGOs (Union of Concerned Scientists, etc.), public agencies and partners to increase the international awareness of the threat from *C. cactorum* to ecosystems and biodiversity in regions where opuntia are conservation targets or would potentially support dispersal of *C. cactorum* because opuntia hosts are present. The Nature Conservancy identifies threats from *C. cactorum* to biodiversity and develops or participates in monitoring and research efforts where appropriate.

- The Nature Conservancy, the Comisión Nacional de Biodiversidad, CONABIO (National Commission for Biodiversity of Mexico) and others develop awareness and co-operation within the U.S. National Invasive Species Council, Global Invasive Species Programme, and International Union for the Conservation of Nature and Natural Resources to reduce dispersal, and increase detection and eradication of *C. cactorum*.

7. RECOMMENDED ACTIONS

The introduction, spread and establishment of the cactus moth would have devastating economical, ecological, and social effects not only to the US, Mexico and the Caribbean region but also in countries of Central and South America, and other regions. In some countries, such as Peru, the production of cochineal dye is an important part of the local economy and social stability. In Chile the cactus export industry and in Brazil the large-scale production of cactus forage would be seriously affected. Similarly affected would be some countries of the Mediterranean Basin, such as Italy and Tunisia, which have an important cactus industry; and also some other developing countries where cactus is a source of food for people and livestock. The FAO CACTUSNET has 29 member countries from all continents involved in cactus pear production.

To the IAEA:

1) Applying the SIT/F1 sterility as part of an area-wide integrated approach appears feasible to deal with cactus moth invasions. No other eradication tools are currently available or foreseen that can effectively stop the spread of this pest. The IAEA has the mandate and expertise in using this technology and should thus make every effort to facilitate its development and application against the cactus moth.

2) In view of the global impact and potential role of SIT, an Interregional Technical Co-operation Project is recommended for approval for the 2003-2004 programme cycle. Countries that would immediately participate in such a project would be Cuba, Mexico, South Africa and the United States and possibly Costa Rica and Nicaragua, and other interested countries in the Caribbean, Mediterranean Basin, South America, etc., would join as the project develops.

3) Apart from the Agricultural Departments, the Agency should establish contacts with the Environmental Protection Agencies of Member States to involve them as stakeholders in such an interregional project.

To Member States:

1. Establish immediate collaboration between the affected countries through an IAEA interregional technical co-operation project.

2. Prepare the legal instruments that would allow the enforcement of regulatory actions to prohibit the movement of opuntia plants. This is particularly significant for currently affected countries and those at immediate risk of a *C. cactorum* invasion.

3. Prevent the further spread of the pest in the case of countries such as the USA, where an invasion of *C. cactorum* has taken place and recent data indicate that the rate of spread of the pest is much faster than previously anticipated. It is recommended that the USA immediately embark on an action programme against *C. cactorum*; this should occur regardless of the need for simultaneous efforts in research and development to define detection and eradication tools.

4. Create awareness of the problem at higher levels in the respective Governments including environmental and plant protection agencies, through contact with these agencies, the CACTUSNET, IUCN, and GISP.

5. Create awareness of the problem among growers, biodiversity and genomic conservation organizations, and institutions that could serve as sources of support and influence through education and communication campaigns.

6. Raise the *C. cactorum* issue before the North American Plant Protection Organization (NAPPO) during its next meeting to be held in October 2002 in Oaxaca, Mexico.

7. Implement the collaborative activities that have been identified:

    - Establishment of regular shipments of *C. cactorum* pupae from South Africa to the USA for basic population ecology studies and for initial pest containment purposes.

    - Establishment of a regional *C. cactorum* detection network including extending the trapping network along the Gulf of Mexico, establishing a detection network in the Yucatan Peninsula and throughout the susceptible areas in Cuba.

    - Group training to share the basic monitoring and control procedures available in the USA and South Africa.

    - Preparation and distribution to participating countries field guidelines for establishment and operation of trapping networks and for eradication actions in case of an outbreak in free areas or for control in case of established populations.

    - Organization of workshops for extension workers, and plant and environmental protection staff.

8. Focus research and development efforts on cost-effective tools for monitoring and control of the pest. Research should concentrate on:

    - Development of a cost-effective trapping system including a male or female synthetic lure.

    - Refinement of effective radiation dose for F1 sterility.

    - Adaptation of methods to release sterile moths.

    - Assessment of dispersion rates.

    - Assessment of host range (number of species at risk).

    - Assessment of susceptible areas and impact of indigenous natural enemies.

- Development of an artificial diet for mass rearing.

- Determination of an effective radiation dose for females used as live bait.

9. The following feasibility studies need to be conducted:

    - A HACCP (Hazard Analysis and Critical Control Point) analysis to measure the potential risks of further spread, introduction and establishment of the pest. This analysis would also identify weak points in the quarantine, detection and eradication system that need strengthening to prevent the event (i.e., introduction/establishment of *C. cactorum*) from occurring.

    - Analysis of the potential economical and ecological impact of the pest to assess the magnitude of the potential damage. This study would be used as part of the efforts to raise the attention of decision makers at high levels in the government and NGO's.

    - Technical analysis on the feasibility of SIT application to eradicate or contain current populations in USA, Cuba and other Caribbean Islands and possible outbreaks in countries at risk.

To NGO's:

1. Increase communication efforts with Governments, international organizations and the public to make them more aware of *C. cactorum* impacts and the need for action.

2. Become involved in survey, monitoring, prevention, research, and restoration efforts.

To FAO :

1. Through the FAO Cactus Network, create awareness at an international level of the dangers of *C. cactorum* introduction for countries where cactus are important for economical, ecological or social reasons.

2. CACTUSNET Pest and Diseases Working Group to develop international education, training, and research programs.

8. CONCLUSIONS

- *Cactoblastis cactorum* establishment in cactus-growing areas will be devastating. Irreparable ecological and economical damage as well as irreparable social effects are still to be avoided providing that further spread is curtailed.

- An immediate containment/eradication programme of *C. cactorum* in the southeastern USA, Cuba and other Caribbean islands and particularly along the leading edge of invasion must be launched while the chances of containment and control are still possible.

- The SIT approach was identified as the most promising eradication tool and a critical element of any containment and eradication programme. Sufficient knowledge is available to launch the programme.

- The threat of *C. cactorum* is not fully appreciated by decision makers, particularly in the USA. An effective awareness and regulatory national and international programme should be immediately implemented.

- More research and development is needed to refine and increase efficacy of the control and prevention methods.

- Although the emphasis may initially focus on Mexico, Cuba, other Caribbean islands and the USA, this does not mean that the threat is less important in other countries. Any effective contingency /eradication programme developed under the proposed project will be available for application in any other country.

- A collaborative effort among several countries and all available expertise on *C. cactorum* should be mobilized in this programme.

ANNEX 1. WORK PLAN 2003-2005

PART 1. IAEA CONTRIBUTION

ACTIVITY	DESCRIPTION	INPUTS	ESTIMATED BUDGET (US $)	DATES
I. Feasibility studies	1. Hazard analysis 2. Economical and Ecological impact assessment 3.Technical/economical feasibility of areawide SIT application	1. Three two week expert missions		First quarter 2003
SUBTOTAL			**20,000**	
II. Workshops	1. Interregional Workshop for senior staff of Plant and Environmental Protection Agencies	1. 3 day workshop 2. Recruitment of 10 country representatives 3. Recruitment of 2 experts 4. Duty travel of 1 IAEA staff member	20,000	Jan 2003
	2. Promotional workshops for extension agents, plant and environmental protection staff and NGO's	5. Two 3 days workshop in Florida and Cuba 6. Recruitment of 15 technicians (x2) 7. Recruitment of 2 experts (x2)	20,000	Second quarter 2003
SUBTOTAL			**40,000**	
III Group Training	1. Hands on training for plant and environment protection technical staff on monitoring and control tools and pest management	1. Two 1 wk group training 2. Recruitment of 15 technicians (x2) 3. Recruitment of 2 experts (x2)		First quarter 2003 First quarter 2004
SUBTOTAL			**40,000**	
IV Expert missions	1. Expert missions to Cuba, Mexico, Florida, etc., for preparation of action plans and technology transfer	1. Four 2 wk expert missions to Cuba, Mexico, Florida, Central America		Second quarter 2003 First quarter 2004 First quarter 2005
SUBTOTAL			**25,000**	
V. Fellowships/ Scientific Visits	1. For transfer and collaborative development of technology.	1. Two FE (6 mo) and Two SV (1 mo)	**40,000**	2003 2004
SUBTOTAL			**40,000**	
VI. Subcontracts	1 Pilot production and shipping of *C. cactorum* pupae from South Africa to Florida for SIT field evaluations 2 Pheromone production and field validation	1. Hand labour for field collections and handling of biological material in lab 2. Materials for pupae holding, packing and shipping		2003-2005
SUBTOTAL			**25,000**	
VI. Equipment and materials		1. Cages, traps, solutions, shipping containers, etc		First quarter 2003, 2004, 2005
SUBTOTAL			**35,000**	
TOTAL 3 YRS			**225,000**	

PART 2. MEMBER STATES AND OTHER ORGANIZATIONS CONTRIBUTION

ACTIVITY	DESCRIPTION	INPUTS	ESTIMATED BUDGET (US $)
I. Feasibility studies	1. Hazard analysis 2. Economical and Ecological impact assessment 3. Technical feasibility of SIT application	1. Logistic support for experts 2. Studies on disemination routes prepare Cuba available for experts 3. Study on likely distribution sites in Cu available for experts 4. Pest risk assessment prepared by Cuba available for experts	20,000 5000 5000 5000
SUBTOTAL			**35,000**
II. Workshops	1. Interregional Workshop for senior staff of Plant and Environmental Protection Agencies 2. Promotional workshops for extension agents and plant and environmental protection staff	1.Administration/logistics, local travel, meeting facilities, field trips, etc	20,000
SUBTOTAL			**20,000**
III Group Training	1. Hands on training for plant and environment protection technical staff on monitoring and control tools and pest management	1. At least 1 Workshop per country for local staff	120,000
SUBTOTAL			**120,000**
IV Expert missions	1. Expert missions to Cuba, Mexico, Florida, etc for preparation of action plans and technology transfer through	1. Administrative support, local transportation, facilities (office, lab, etc.,)	25,000
SUBTOTAL	**SUBTOTAL**		**25,000**
V. Fellowships/Scientific Visits		1. Twelve moths of fellowships and 2 months of scientific visits	20,000
SUBTOTAL			**20,000**
VI. Research and Development	1 Development and evaluation of F1 sterility for SIT 2 Pheromone identification and evaluation	Scientists, technicians, laboratories and utilities	
SUBTOTAL			**310,000**
VII. Equipment and materials	Vehicles, windtunnels, GC-supplies, electroantenogram, etc.		
SUBTOTAL			**120,000**
VIII. National Campaigns for communication, education and pest exclusion		Development and distribution of educational materials Scientific conferences Exclusion activities (quarantine enforcement and surveys) Mexico awareness and exclusion campaign 2003	60,000 20,000 20,000 600,000
SUBTOTAL			**700,000**
TOTAL			**1,350,000**

ANNEX 2. LIST OF KNOWN HOSTS OF *CACTOBLASTIS CACTORUM*

Opuntioideae (Platyopuntiae)

New Associations		Old Associations	
Opuntia ficus-indica	XX	*Opuntia aurantiaca*	XXX
Opuntia compressa (humifusa)	XXX	*Opuntia vulgaris*	XXX
Opuntia engelmannii	X	*Opuntia salmiana*	XX
Opuntia spinulifera	XX	*Opuntia bonaerensis*	XXX
Opuntia streptacantha	XX	*Opuntia cordobensis*	XX
Opuntia stricta	XXX	*Opuntia quimilo* (small plants)	X
Opuntia triacantha	XXX	*Opuntia discolor*	XXX
Opuntia tomentosa	X	*Opuntia retrorsa*	XXX
Opuntia microdasys	X?	*Opuntia salagria*	XX
Opuntia repens	XXX	*Opuntia paraguayensis*	XXX
Opuntia tuna	XXX		
Opuntia elatior	XXX	Several other unidentified species in Argentina, Uruguay and Paraguay	
Opuntia pusilla	XXX		
Opuntia corallicola	XXX		
Opuntia cubensis	XXX		

Cylindropuntiae

Opuntia imbricata	X	*Opuntia glomerata*	X
Opuntia tunicata	X		

XXX = excellent host: XX= good host: X=marginal host
(The table is incomplete and latin names need to be verified according to latest published lists)

ANNEX 3.A - CURRENTLY UNDERSTOOD STATUS OF *CACTOBLASTIS CACTORUM* IN COUNTRIES CULTIVATING OPUNTIA.

COUNTRY	STATUS OF *C. CACTORUM*
ARGENTINA	Commercial production commenced in about 1980. Despite the presence of a large complex of co-evolved natural enemies, *C. cactorum* remains a serious pest in cultivations. Insecticides are the preferred method of control. Peasant farmers increasingly rely on *O. ficus-indicta* as a source of fruit and they seldom have the means to control *C. cactorum*.
AUSTRALIA	Cultivation of useful Opuntia species is discouraged for fear of conflicts of interest. Only recently has some cultivation been initiated. The status of *C. cactorum* at this stage is unknown, but it is expected that it will be similar to the status in South Africa.
CUBA	Cactus pear as a source of fruit is limited to isolated plants in gardens. The impact of *C. cactorum* is not yet known. Cuba is initiating a project to increase cultivation and uses of cactus pear. *C. cactorum* may thus become a limiting factor as it is already present in the eastern part of Cuba.
DOMINICAN REPUBLIC	*C. cactorum* is present and contaminating exports of horticultural cacti.
NAMIBIA	*C. cactorum* is present in some areas of *O. ficus-indica* cultivation, where the moth is a problem. However, there are also infestations of *O. stricta* that require control by *C. cactorum*.
SOUTH AFRICA	Although not a limiting factor, *C. cactorum* is regarded as a serious pest in cultivations of *O. ficus-indica* and *O. robusta* cultivars. Control methods (chemical and mechanical) are necessary to protect plants and to maintain production. Cactus pear is becoming increasingly important to emerging/small/subsistence farmers who do not have the means to control *C. cactorum*.
UNITED STATES OF AMERICA	Limited surveys have detected *C. cactorum* in cultivated opuntia in gardens in Florida, Georgia, and South Carolina. The horticultural industry has not yet been impacted. *C. cactorum* has not yet reached the large horticultural cultivations in the southwestern U.S.A.

ANNEX 3.B - COUNTRIES THAT CULTIVATE CACTUS PEAR AND WHICH ARE THREATENED BY *CACTOBLASTIS CACTORUM* INVASIONS

COUNTRY	SPECIES CULTIVATED	ESTIMATED AREA HA. UNDER CULTIVATION	PRODUCTS	REMARKS
Brazil	*O.ficus-indica* *O. robusta* (many cultivars)	400 000	Mainly fodder, Also fruit	Cultivations are expanding
Chile	O.ficus-undica (many cultivars)	10 000	Cochineal Fruit	Export fruit and high income cochineal production
Peru	O.ficus-indica (many cultivars)	35 000	Cochineal Fruit Fodder	90% of world cochineal production
Mexico	*O.ficus-indica* *O.streptacantha* *O.robusta* *O.amyclaea* *O.tomentosa* *O.megacantha* And others	360 000	Fruit Fodder Vegetable (nopalitos) Many other byproducts	3 million ha of natural populations are also utilized
Bolivia	O.ficus-indica (several cultivars)	1 000	Fruit Cochineal fodder	Becoming increasingly important
Italy	O.ficus-indica (several cultivars)	30 000	Fruit (export) Fodder medicinal	Mayor industry in Sicily
Spain	O.ficus-indica	1 000	fruit	Mainly non-commercial
Canary slands	O.ficus-indica	1 000	Cochineal fruit	Major income from cochineal
Israel	*O.ficus-indica*	300	fruit	Intensive fruit production
Egypt, Portugal Turkey, Jordan Pakistan, Namibia	*O.ficus-indica*	unknown	Fruit fodder	Starting with production
Tunisia	O.ficus-indica (various cultivars)	80 000	Fruit fodder	Increasing in importance
Other North African countries	O.ficus-indica (many cultivars)	120 000	Fruit fodder	Increasing importance in Morocco and Algeria
Ethiopia, Eritrea Yemen	O.ficus-indica (many cultivars)	31 000 ?	Fruit fodder	Serious conflicts of interest

ANNEX 4. LIST OF NATIVE OPUNTIAE [SUBGENUS: OPUNTIA (PLATYOPUNTIA)] SPECIES BY COUNTRY.

SPECIES	COUNTRY	AUTHORITY	REFERENCE/S
Nopalea brittonii			Benson, 1982
N. guatemalensis	Guatemala		Benson, 1982
N. inaperta	Yucatan		Benson, 1982
Opuntia anacantha	Argentina		Benson, 1982
O. arechavaletai	Uruguay, Argentina		Benson, 1982
O. arenaria	USA/Canada, Mexico	Engelmann	Benson, 1982; Bravo-Hollis, 1978
O. argentina	Argentina		Benson, 1982
O. atrispina	USA/Canada, Mexico	Griffiths	Benson, 1982; Bravo-Hollis, 1978
O. atropes	Mexico	Rose	Bravo-Hollis, 1978
O. auberi	Mexico		Benson, 1982
O. aurantiaca	Uruguay, Argentina	Lindley	Benson, 1982
			Benson, 1982
O. azurea	Mexico	Rose	Bravo-Hollis, 1978
O. basilaris	USA/Canada, Mexico	*Engelmann & Bigelow*	Benson, 1982; Bravo-Hollis, 1978
O. bella	Colombia		
O. bensonii	Mexico	Sanchez-Mejorada	Bravo-Hollis, 1978
O. bergeriana			Benson, 1982
O. boldinghii	Curacao, Trinidad, Venezuela		Benson, 1982
O. bravoana	Mexico, Canada	Baxter	Bravo-Hollis, 1978
O. brasiliensis	USA/Canada	(Wildenow) Haworth	Benson, 1982
O. cardiosperma	Paraguay		Benson, 1982
O. canina	Argentina		Benson, 1982
O. cantabrigiensis	Mexico	Lynch	Bravo-Hollis, 1978
O. catingicola	Brazil		Benson, 1982
O. chaffeyi	Mexico	Britton & Rose	Benson, 1982
O. chlorotica	USA/Canada, Mexico	*Engelmann & Bigelow*	Benson, 1982; Bravo-Hollis, 1978
O. cochenillifera	USA/Canada	(Linnaeus) Salm-Dyck	Benson, 1982
O. compressa	Mexico	(Salisbury) Macbride	Bravo-Hollis, 1978
O. corallicola	USA		Benson, 1982
O. crassa	Mexico	Haworth	Bravo-Hollis, 1978
Species	**Country**	**Authority**	**Reference/s**
O. cubensis	USA/Canada	Britton & Rose	Benson, 1982
O. curassavica	W Indies		Benson, 1982
O. dejecta			Benson, 1982
O. decumbens	Mexico, Guatemala	Salm-Dyck	Bravo-Hollis, 1978
O. delaetiana	Paraguay		Benson, 1982
O. depressa	Mexico	Rose	Bravo-Hollis, 1978
O. distans	Argentina		Benson, 1982
O. durangensis	Mexico	Britton & Rose	Bravo-Hollis, 1978

O. echios	Galapagos Is.		Benson, 1982
O. elata	Brazil, Paraguay		Benson, 1982
O. elatior	Curacao, Panama, Venezuela		Benson, 1982
O. erinacea	USA/Canada, Mexico	Engelmann & Bigelow	Benson, 1982; Bravo-Hollis, 1978
O. excelsa	Mexico	Sanchez-Mejorada	Bravo-Hollis, 1978
O. falcata	Haiti		Benson, 1982
O. ficus-indica	USA/Canada, Mexico	(linnaeus) Miller	Benson, 1982; Bravo-Hollis, 1978
O. fragilis	USA/Canada, Mexico	(Nutall) Haworth	Benson, 1982; Bravo-Hollis, 1978
O. fuliginosa	Mexico	Griffiths	Bravo-Hollis, 1978
O. galapageia			Benson, 1982
O. glaucescens	Mexico	Salm-Dyck	Bravo-Hollis, 1978
O. grandis	Mexico	Pfeiffer	Bravo-Hollis, 1978
O. grosseiana	Paraguay		Benson, 1982
O. guilanchi	Mexico	Griffiths	Bravo-Hollis, 1978
O. hanburyana			Benson, 1982
O. helleri	Galapagos Is.		Benson, 1982
O. huajuapensis	Mexico	Bravo	Bravo-Hollis, 1978
O. humifusa	USA/Canada	(Rafinesque) Rafinesque	Benson, 1982
O. hyptiacantha	Mexico	Weber	Bravo-Hollis, 1978
O. inamoena	Brazil		Benson, 1982
O. insularis	Galapagos Is.		Benson, 1982
O. jaliscana	Mexico	Bravo	Bravo-Hollis, 1978
O. joconostle	Mexico	Weber	Bravo-Hollis, 1978
O. karwinskiana	Mexico		Benson, 1982
O. kiska-loro	Argentina		Benson, 1982
O. lasiacantha	Mexico	Pfeiffer	Bravo-Hollis, 1978
O. leucotricha	USA/Canada, Mexico	De Candolle	Benson, 1982; Bravo-Hollis, 1978
O. lindheimeri	USA/CANADA, MEXICO	Engelmann	Benson, 1982; Bravo-Hollis, 1978
O. littoralis	USA/Canada, Mexico	Engelmann	Benson, 1982; Bravo-Hollis, 1978
O. macanadadou-galiana	Mexico		Benson, 1982
O. macrantha	Cuba		Benson, 1982
O. macrorhiza	USA/Canada, Mexico	Engelmann	Benson, 1982; Bravo-Hollis, 1978
O. megacantha	Mexico	Salm-Dyck	Bravo-Hollis, 1978
O. megasperma	Galapagos Is.		Benson, 1982
O. microdasys	Mexico	(Lehmann) Pfeiffer	Bravo-Hollis, 1978
O. microdisca	Argentina		Benson, 1982
O. mieckleyi	Paraguay		Benson, 1982
O. millspaughii	Cuba, Bahamas		Benson, 1982
O. moniliformis	Hispaniola, Puerto Rico		Benson, 1982

O. montevidensis	Uruguay		Benson, 1982
O. nejapensis	Mexico	Bravo	Bravo-Hollis, 1978
O. neochrysacantha	Mexico	Bravo	Bravo-Hollis, 1978
O. nicholii	USA/Canada	L. Benson	Benson, 1982
O. orbiculata	Mexico		Benson, 1982
O. oricola	USA/Canada, Mexico	Philbrick	Benson, 1982; Bravo-Hollis, 1978
O. palmadora	Bahia, Brazil		Benson, 1982
O. pailana	Mexico	Weingart	Bravo-Hollis, 1978
O. pascoensis	Peru		Benson, 1982
O. phaeacantha	USA/Canada, Mexico	Engelmann	Benson, 1982; Bravo-Hollis, 1978
O. pilifera	Puebla, Mexico	Weber	Bravo-Hollis, 1978
O. plumbea	Mexico	Rose	Bravo-Hollis, 1978
O. polyacantha	USA/Canada, Mexico	Haworth	Benson, 1982; Bravo-Hollis, 1978
O. puberula	Mexico	Pfeiffer	Bravo-Hollis, 1978
O. pubescens	Mexico, Guatemala	Wendland	Bravo-Hollis, 1978
O. pumila	Mexico	Rose	Bravo-Hollis, 1978
O. pusilla	USA/Canada	(Haworth) aworth	Benson, 1982
O. pycnantha	Mexico, Canada	Engelmann	Bravo-Hollis, 1978
O. pyriformis	Mexico	Rose	Bravo-Hollis, 1978
O. quimilo	Argentina		Benson, 1982
O. quitensis	Ecuador		Benson, 1982
O. rastrera	Mexico	Weber	Bravo-Hollis, 1978
O. repens	W Indies		Benson, 1982
O. rileyi	Mexico	Gonzalez Ortega	Bravo-Hollis, 1978
O. robusta	Mexico	Wendland	Bravo-Hollis, 1978
O. rubescens	W Indies		Benson, 1982
O. rufida	USA/Canada, Mexico	Engelmann	Benson, 1982; Bravo-Hollis, 1978
O. saxicola	Galapagos Is.,		Benson, 1982
O. scheeri	Mexico	Weber	Bravo-Hollis, 1978
O. schickendantzii	Argentina		Benson, 1982
O. schumannii	South America		Benson, 1982
O. soehrensii	Peru, Bolivia, Argentina		Benson, 1982
O. spinulifera	Mexico	Salm-Dyck	Bravo-Hollis, 1978
O. spraguei	Mexico	Gonzalez Ortega	Bravo-Hollis, 1978
O. stenarthra	Argentina, Paraguay		Benson, 1982
O. stenopetala	Mexico, Coahuila	Engelmann	Bravo-Hollis, 1978
O. streptacantha	Mexico	Lemaire	Bravo-Hollis, 1978
O. stricta	USA/Canada, Mexico	Haworth	Benson, 1982; Bravo-Hollis, 1978
O. strigil	USA/Canada, Mexico	Engelmann	Benson, 1982; Bravo-Hollis, 1978
O. sulphurea	Chile, Argentina		Benson, 1982
O. tapona	Mexico, Canada	Engelmann	Bravo-Hollis, 1978

O. taylorii	Hispaniola		Benson, 1982
O. tehuantepecana	Mexico	(Bravo) Bravo	Bravo-Hollis, 1978
O. tomentella	Mexico	Berger	Bravo-Hollis, 1978
O. tomentosa	USA/Canada, Mexico	Salm-Dyck	Benson, 1982; Bravo-Hollis, 1978
O. triacantha	USA/Canada	(Willdenow) Sweet	Benson, 1982
O. tuna	Jamaica		Benson, 1982
O. undulata	Mexico	Griffiths	Bravo-Hollis, 1978
O. utkilio	Argentina		Benson, 1982
O. velutina	Mexico	Weber	Bravo-Hollis, 1978
O. violacea	USA/Canada, Mexico	Engelmann	Benson, 1982; Bravo-Hollis, 1978
O. vulgaris	USA/Canada	Miller	Benson, 1982
O. wentiana	Curacao, Venezuela		Benson, 1982
O. wilcoxii	Mexico	Britton & Rose	Bravo-Hollis, 1978
Tacinga funalis	Brazil		Benson, 1982

ANNEX 5. LIST OF PARTICIPANTS

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ANNEX 6. MEETING PRESENTATIONS

See attached disk.

ANNEX 7. LIST OF EXPERTS PRESENTLY INVOLVED WITH *CACTOBLASTIS CACTORUM*

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ANNEX 8. LIST OF RELEVANT LITERATURE AND DOCUMENTS

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