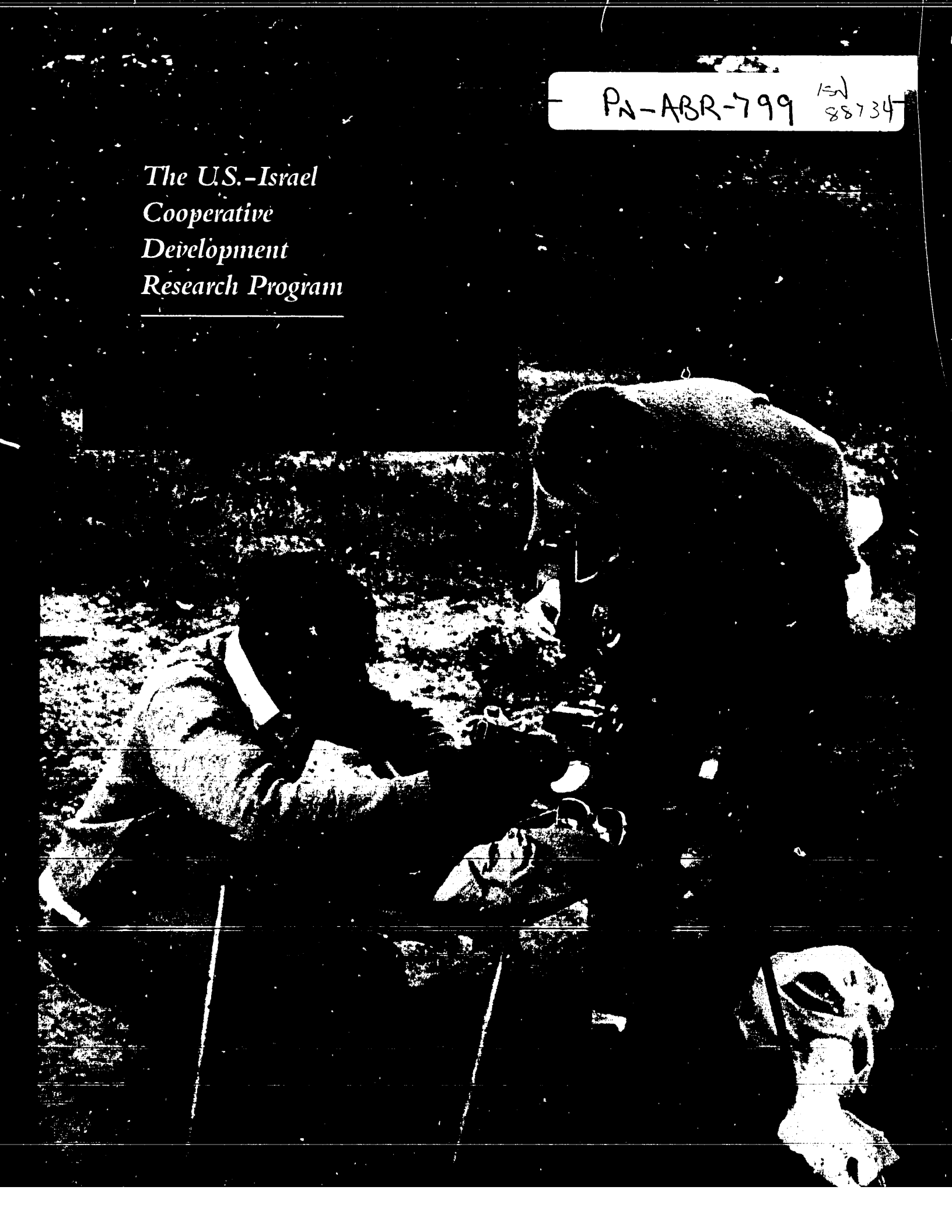
PN-ABR-799 ISN 88734

The U.S.-Israel Cooperative Development Research Program



The U.S.-Israel Cooperative Development Research Program

Office of Research

U. S. AGENCY FOR INTERNATIONAL DEVELOPMENT

WASHINGTON, D.C.

December 1993

"... developing countries require extensive scientific and technological capacity in order to deal effectively with their development problems, relate to the industrialized nations, and constructively participate in the shaping of a stable world order."

— International Development Cooperation Act of 1979

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Left: Investigator Chumpol Pholpramool counts sperm removed from a male rat after treatment with sulphapyridine in a CDR project with Thailand to develop a male antifertility drug.

Introduction

"The United States and Israel share many common objectives ... chief of which is the building of a better world, a world in which every nation can develop its resources and develop them in freedom and peace."

— *Lyndon Johnson, U.S. president*

The U.S.-Israel Cooperative Development Research Program (CDR) is a partnership, catalyzed by U.S. funds, that encourages Israeli and developing-country scientists to collaborate in solving development problems in the Third World. The program demonstrates how a partnership between the United States and Israel can efficiently and effectively offer benefits to other countries.

Israel brings to CDR a unique development expertise gained through the struggle of building a new nation in an arid land. During the decades before Israel's creation in 1948, Jewish settlers learned to cope with endemic diseases and to live—even thrive—in the hot, dry climate. In the first 30 years of its official existence, Israel managed to accept heavy immigration, including large numbers of Jews displaced by World War II, while maintaining robust economic growth. In the past 20 years, Israel has maintained a 1.5 percent-per-year increase in per capita gross national product, which now ranks among those of the world's upper-income nations. Israel has done so by marshaling the ingenuity and skills of its people and by creating an exceptionally effective nationwide program that brings the scientific method to bear on the problems of development.

CDR symbolizes the close, long-time relationship between the United States and Israel and their mutual desire to assist the developing countries of the world. Over the last two decades this association has grown closer as the two countries embarked on joint efforts in science, industry and agriculture (see box, page 37). In 1985, CDR was created by the U.S. Agency for International Development (USAID) to share the advantages of this partnership with developing countries throughout the world. CDR founders recognized Israel's expertise in using state-of-the-art science and technology to solve development problems. With U.S. financial help, the Israeli expertise could be shared with developing countries through a program of collaborative research.

Like many developing countries, Israel has little natural wealth. It has a sea coast, some fresh water, desert, sunshine and the intellectual assets of its people. Israel has sought to maximize the use of these resources. The country is famous for the rapid transformation of its arid lands into a rich source of agricultural products. Thus, in some cases Israel can cooperate on crops of mutual interest with Mediterranean countries, such as Morocco and Portugal, or with arid countries, such as Chile and Mexico. In other cases Israel can share its experience in adapting and developing new crops for underexploited lands with countries such as Thailand and the Philippines, which are following a science-based development path similar to the one Israel has taken.

The expertise behind today's Israeli economy has much to offer developing countries. Although known internationally for its success with desert agriculture, Israel has an urbanized society and an industrialized, export-oriented economy. About 90 percent of the country's 5 million inhabitants live in urban areas. The industrial sector generates 30 percent of Israel's gross domestic product and accounts for more than 90 percent of exports. The agriculture sector produces more fruit, vegetables, poultry and dairy products than the country needs, and sale of the surplus pays for the foods, such as sugar and coffee, that Israel imports. Both industry and agriculture concentrate on producing high-value products—winter fruits and vegetables, computer software and hardware—making maximum use of scarce natural resources and the country's expertise in science and technology.

CDR has excellent cooperation with scientists in fields, particularly agriculture, representing much of Israel's economic success. Many CDR projects involve the management of water resources for agri-

cultural uses, development of new crops, protection against agricultural pests and development of aquatic resources such as seafood and algae. The program also has good interaction with Israel's biomedical research community, which has expertise in tropical diseases, such as malaria and leishmaniasis, common in many developing countries. In the future, perhaps, CDR will have comparable success tapping other areas of Israel's expertise.

The recent fall of Communism in East Europe and the Soviet Union has uncovered another development niche that Israel is particularly well-suited to fill. Many Israeli scientists have personal and cultural ties with those regions and are fluent in Polish, German, Russian or another language spoken there. Thus, scientific collaboration of the type fostered by CDR is fairly easy for them and has a high potential for success (see box, page 36). In addition, many scientists and technicians from the former Soviet Union and East Europe have emigrated to Israel, where they are now in an ideal position to foster collaboration with their countries of origin.

CDR is a small program, less than 1 percent of USAID's current research and development effort. CDR and its sibling, the Program in Science and Technology Cooperation (PSTC; see box, page 37), represent the cutting edge of USAID's development research. These programs fund the risky initial phase of research that tests hypotheses aimed at solving development problems. If a hypothesis is proved, then follow-on research and development can be taken over by other USAID programs or private enterprise.

CDR is an experiment that responds to new circumstances in the world. At a time when poverty, disease and hunger are ravaging the developing world and the door to economic development is opening in East Europe, this program offers hope and an opportunity to give countries in these regions the scientific and technological means to raise themselves to a higher standard of living.

Agricultural Water Resources

"Settling and developing the Negev—that is Israel's greatest and most difficult challenge. We can cope with it if we use the two qualities with which we have been blessed: a pioneering and scientific spirit."

— David Ben-Gurion, Israeli prime minister

One-third of the earth's land surface is arid or semiarid terrain where water is a precious commodity. Many developing countries lie in these regions, and their growing populations are increasing the pressure to expand food production. Most of the countries with limited water resources are in Africa and the Middle East, where populations are growing the fastest.

In particular, more than half the people in North Africa and the Middle East live in countries with scarce water resources, and nearly another fifth of the people in these regions live in countries where scarcity becomes a problem in years of low rainfall. When water is scarce and food supplies shrink, hundreds of thousands of people suffer poor nutrition or face outright starvation.

Modern science and technology offer innovative ways for water-short countries to find more water and stretch its use. More efficient irrigation techniques such as drip irrigation are being explored. The development of salt-tolerant plants means that saline water, which often abounds in arid lands, can be used to grow certain vegetable and cereal crops. Innovative methods are being developed to capture scarce rain water before it runs off the land. Improved techniques are being created for monitoring—and thereby exploiting—underground water. And high-value crops, such as cut flowers and winter vegetables for export, are being selected to cultivate under irrigation so that scarce water earns the highest possible returns.

Workers install a water-level recorder at a stream in northeast Thailand, where a CDR team is studying the hydrology of rainfed paddy (rice land). Knowledge gained from the study should allow more efficient use of rainwater in rice farming.

In Israel, water shortage is a fact of life. Water-use efficiency for crop irrigation is 85 to 90 percent, making the country a model for the rest of the world. Israel has developed technologies for the use of saline water that are on the cutting edge of irrigation research. Israeli scientists have also developed improved ways to manage scarce irrigation water and to make better use of rainwater and ground water.

New Irrigation Techniques

In many arid and semiarid countries with growing populations, the best available alternative for expanding agricultural production is the use of marginal (sandy) soils and lower quality (saltier) water for irrigation. In the long run, the development of salt-tolerant plant varieties is an important step in expanding the use of saline water. But theoretical and laboratory studies have suggested that providing key nutrients through carefully timed fertilization might increase the tolerance of salt-sensitive plants to the point where they can produce significant yields, even when using saline water for irrigation.

In 1986, researchers from Israel teamed with scientists in the Philippines under a CDR grant to learn whether enhanced fertilization could be used to produce peanuts, corn, tomatoes, watermelons, sunflowers and other locally important crops with saline water during the Philippine dry season. They fertilized peanuts with potassium nitrate (KNO_3) and used a trickle irrigation system to deliver saline water during the dry season. The peanut yield in the experimental fields turned out to be three times the local average. If such yields with saline water are sustainable, Philippine farmers may be able to produce a second cash crop during the dry season, when fields are normally idle owing to lack of fresh water. Work based on this experience is being carried out not only in Israel and the Philippines but also in Thailand, Kenya, Mexico, Portugal and Spain.

The Philippine CDR project produced at least one important spinoff. The investigators observed that potassium deficiency caused changes in specific sunflower proteins. That information may lead to the development of a diagnostic test which could detect potassium deficiency early enough to correct it by appropriate fertilization. Diagnostic kits for other mineral deficiencies might also be developed for use by farmers to guide fertilizer application.

The investigators also found that peanuts and corn grown with saline water plus enhanced fertilization are still sensitive to salt during certain growth stages. So under a 1991 grant, the CDR team set out to identify growth periods of high salt sensitivity in selected crops and to develop means to bypass that sensitivity, particularly by applying supplemental fresh water during the critical growth phases. Greenhouse studies began by evaluating the effects of saline water applied to wheat plants at various growth stages and the ability of nitrogen, from nitrate (NO_3^-) or ammonium (NH_4^+), to alleviate the salinity effects. The scientists found that wheat is most sensitive to salt during early vegetative growth but becomes increasingly tolerant with maturity. They therefore recommend that saline irrigation should be started after vegetative growth has advanced. In addition, the scientists found that ammonium was better at stimulating vegetative growth at early stages but that nitrate tended to fill the grains better. Such understanding of plant physiology leads to more efficient use of fertilizer. The results of these CDR projects should be applicable to other countries in Asia, Africa and South America where salinity problems exist.

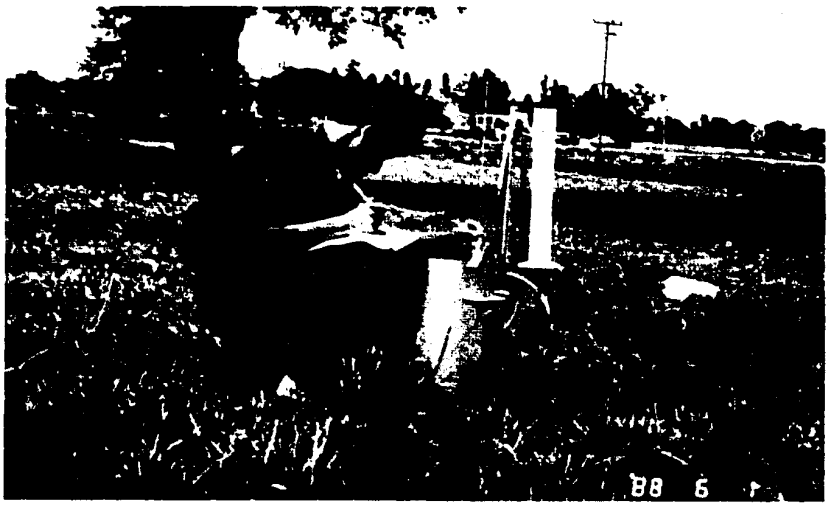
Sand is particularly well suited to trickle-drip irrigation with brackish water–often the only water available in desert regions–because the infrequent rains are able to flush accumulated salts from the sand with relative ease. Although trickle-drip irrigation is initially expensive, it can be very economic in dry regions where the most efficient level of fertilizers can be delivered through fertigation (adding fertilizer to irrigation water) directly to the roots, with little risk of the nutrients' being washed away by a rainfall.

Mature ears of corn, grown in a CDR project with the Philippines, demonstate this crop can be successfully irrigated with saline water plus nitrogen. Small ears on left were grown with low nitrogen and fresh or saline water. Large ears on right were grown with high nitrogen and fresh or saline water.

Israeli and Peruvian scientists are coupling saline-irrigation techniques with advanced sand culture methods to extend saline irrigation to sandy, marginal lands. The investigators are growing crops with highly saline water by using a well-aerated growth medium, such as sand or gravel, and supplementing the water with appropriate nutrients. The team has obtained reasonably good yields using this regimen to grow lettuce, cabbage, tomato, sweet potato and asparagus. The results may open up the opportunity to use highly saline water to grow crops on sand dunes, coastal areas and islands that have little soil or fresh water.

In related work with Ghana, CDR scientists are investigating all aspects of desert sand sheets to assess their potential for agricultural development using modern irrigation techniques. The scientists are employing methods, recently developed for studying sand dunes, to investigate bimodal sand sheets, which have both fine and coarse sand grains. Fine grains tend to be carried by the wind. Their bombardment, or saltation, can damage plants. Larger sand grains tend to roll, or creep, when pushed by the wind. One focus of the research therefore is on assessing the stability of sand sheets under cultivation and the likelihood of damage to plants.

Israelis have also become expert at making better use of the fresh water that is available for irrigation. Thus, Israeli scientists are using a CDR grant to develop a methodology for evaluating the effectiveness of different irrigation systems in terms of the irrigation/crop-



An investigator measures rainwater infiltration on upland during a CDR project in Thailand to study the hydrology of rainfed paddy (rice land).

yield relationship and overall economics. They are collaborating with investigators in Swaziland to compare the results from identical field trials in each country. They will test sprinkler, drip and furrow irrigation systems at two different frequencies, paying special attention to variations in transpiration and the uniformity of water application.

Nonuniform water application can waste scarce water and hurt crop yields, but increasing uniformity generally means higher costs for more advanced irrigation technology. Data from this project will help agriculturalists determine scientifically when the use of a costlier, more effective irrigation system would improve the overall economy of a crop, given the particular environmental conditions. The results should also help agriculturists develop a system to predict how well crops will produce at various locations and in different climates.

Transporting water to irrigation sites has also been studied extensively by Israeli scientists. Their findings may benefit the Philippines, where stabilizing and sealing the soil in irrigation ditches and reservoirs are major problems due to the heavy, intense rainfalls and the high permeability of the soil. With CDR funding, Israeli and Philippine researchers are investigating oil refinery effluents that might be useful for treating the soil in ditches and reservoirs. Since effluents are waste products, they would be less expensive than commercial treatments. And because the effluents are already in emulsion, they could be easily applied without the expense of heating or emulsification required for other materials. Preliminary experiments suggest the effluents are effective, long-lasting sealers. The study is also evaluating the potential risk, estimated to be low, of the effluents to health and the environment.

EXPLOITING RAINWATER

Making better use of rainwater is another approach to dealing with water scarcity, and CDR is funding several innovative projects. Thai researchers are drawing on the expertise of Israeli scientists to help them study the hydrology of rainfed paddy (rice land) in northeast Thailand, where 80 percent of paddy is rainfed. The project scientists are developing a new mathematical model for a watershed, taking into account the unique characteristics of rice land. The families that operate rainfed rice farms generally practice subsistence agriculture. Failure of the rice crop in any one year can be disastrous for most of these families.

With Thailand's growing rural population, the Thai government has been encouraging farmers to expand the construction of small diversion weirs on streams to increase paddy production. Knowledge of the region's hydrology derived from the computer watershed model should lead to a more efficient use of water. Already data from the project have been used for planning small irrigation systems as well as for planning beyond the local level. The models and modeling approach should also be applicable to other countries in Southeast and South Asia where the rural poor subsist on rainfed rice cultivation.

Precious little rain falls in arid and semi-arid lands. Depending on the soil type, up to 50 percent or more of a rainfall may be lost to local farmers through runoff. Researchers have found that the impact of the raindrops and the structure and chemistry of the soil often combine to create a thin crust that impedes water penetration into the soil, increases runoff and, in some cases, inhibits the sprouting of crops.

Israeli and Portuguese scientists received a CDR grant to study the crusting phenomenon in their countries and to explore ways to overcome it. Previous studies in Israel indicated that spreading gypsum—an inexpensive raw material available in many arid lands—on the soil could interrupt the crust-forming process. During the CDR project, the scientists found that the impact of the raindrops is the primary mechanism in crust-forming. They also learned that spreading mulch on the soil is more effective than gypsum for preventing runoff and erosion.

In a follow-up CDR project, the Israelis teamed with scientists in Kenya, where rainfed agriculture is the common practice but where up to 70 percent of a rainfall may be lost to runoff. The overall aim is to improve water management and thereby increase crop production and decrease water-caused soil erosion. In particular, the scientists are studying the ability of covers, such as mulch or crops, and different cultivation methods to reduce runoff and improve crop yields.

Overgrazing and desertification are problems in large areas of semiarid regions in Africa. During years of drought, herders remain close to water sources, and their animals often overgraze the surrounding land. With the ground cover gone, wind and water sweep away the fertile top soil, destroying the pasture land. At the same time, relatively good rangeland goes ungrazed for lack of drinking water. Many methods optimizing the use of available water are too expensive or simply irrelevant to these regions, where agriculture is based on small herds, natural grazing grounds and the minimum water needed for humans and their animals. So scientists in Israel and Kenya investigated ways to design water harvesting systems that could be adapted to local problems, constructed by local means and modified according to local experience, conditions and demands.

Using Israeli expertise in soil physics and other areas, the team constructed three "built-in" water harvesters—natural catchments lined with buried plastic membrane. Rainwater, unable to penetrate the plastic, is conducted through the overlying soil to a small reservoir. A computer model for designing the water harvesters was developed so that engineers in other countries could use it to devise their own water harvesters according to local conditions. If successful, this unconventional method of harvesting water may be applicable where other systems have failed. In that case it would contribute to the well-being, at least on a local scale, of the inhabitants in very problematic areas of semiarid lands.

BETTER GROUNDWATER MANAGEMENT

In many countries, developing as well as developed, groundwater is one of the chief sources of water. Increased demand for water and deterioration in the quality of surface water have intensified the exploitation of groundwater, particularly in arid and semiarid countries with scarce surface water. Intensified farming and expanded industrialization in many developing countries are creating more pollutants, which seep into aquifers and reduce the quality of groundwater.

Scientists in Israel have developed theoretical improvements in mathematical models that can be used to plan and design rational groundwater management. Such models are used to estimate the flow and storage capacity of aquifers by extrapolating from data generated by testing and monitoring observation wells, which are expensive to drill. The new model is designed to make better extrapolations from the limited data available in many developing countries where only a few field measurements of aquifers have been made. Joining Portuguese researchers under a CDR grant, the investigators extended the theoretical work on this stochastic model and successfully applied it to field conditions in Portugal, Israel and the United States.

The advances made by the Israeli-Portuguese team were quickly picked up by a second group of researchers from the United States, Israel, Tanzania, Nigeria and Morocco. With CDR funding, the group set out in 1991 to create a regional groundwater modeling system especially for developing countries. It will use several innovative techniques to reduce the amount of computer calculations needed, thus making the model small enough to fit into microcomputers affordable in developing countries. The model will incorporate and extend the previously developed stochastic analysis, which is suited to the paucity of field data generally found in developing countries. In addition, the software will be produced in several languages, including French and Arabic, for widespread use in developing countries.

Water is an absolute necessity for the people of developing countries, not only for human consumption but also for the agricultural production that feeds their populations and fuels economic expansion. With help from CDR, many of these countries are beginning to develop water resources that may one day lead to self-sufficiency in food production and a healthier, higher standard of living for their people.

WATER AND ANTIPOLLUTION RESEARCH IN EAST EUROPE

The recent collapse of Communism in East Europe and the overthrow of its secretive governments revealed the economic malaise that outsiders have long suspected. The surprise was the breadth of the failure of command industrialization and collective agriculture and the extent of the devastation to the region's environment.

"The cost of fixing the environmental damage is way higher than anyone expected," said a U.S. scientist after meeting with East European colleagues soon after the Communist fall. "The expected costs keep on going up every month."

The development problems that arose under Communism in these countries, their relatively strong scientific infrastructures and their ethnic and cultural links to Israel make such countries obvious candidates for the U.S.-Israel Cooperative Development Research Program (CDR). In 1991, the first year CDR accepted preliminary research proposals from East Europe, the program received 120 of them. The following year more than twice that number were received. Roughly 10 percent of them dealt with the environmental legacy of the Communist years: contamination of water resources and generalized pollution of the environment. One anecdote recounts that children no longer swim in some lakes in the Czech Republic because the metals are so heavily concentrated that they can stain the skin blue during an afternoon swim.

One of the first CDR projects with East Europe, funded in 1992, is looking into ways of dealing with the contamination of soil and water by hazardous organic substances from chemical industries, agrochemicals and waste incinerators in the Czech Republic, as well as in Israel. The investigators are studying the abilities of various clays to adsorb hazardous organic materials. This knowledge will help in the design of technologies to decompose these organic materials or remove them by filtration through columns of clays, soils or sediments. The information will also help determine the conditions for using particular clays and soils to store these hazardous wastes and for slowing the transport rate of organic pollutants through the ground into water supplies tapped for drinking water.

A Czech investigator uses a continuous wave CO_2 laser pyrolysis apparatus to study reactions between ozone and olefins, a class of hydrocarbons found in auto emissions. Data from the CDR study will help authorities deal with air pollution.

Czech scientists are taking a first step toward dealing with air pollution by investigating via CDR the reactions between ozone and olefins, a class of hydrocarbons found in emissions from cars and oil refineries. Air pollution is one of the most serious problems facing East European countries. Before 1989, the problem of environmental pollution was not given high priority in Czechoslovakia. In general, Communist countries allowed the use of industrial technologies long outlawed in the West because of their pollution. Understanding the ozone-olefin reactions is important for constructing realistic models of atmospheric chemistry, and such models are essential in formulating strategies to control air pollution.

In Slovakia, scientists have opened an investigation into the effects of the rapid, large-scale changes in land use that resulted from the collectivization of farms beginning around the 1960s. The CDR project also lays a foundation for understanding the effects of the current "decollectivization." Parts of Israel, which has also had a strong, centralized agriculture policy, have undergone comparably extreme land-use changes since the onset of increased Jewish settlement that followed the establishment of Israel in 1948. The CDR project will study watersheds in the two countries and compare the effects of such abrupt land-use changes on the evolution of the terrain in these catchments. The investigators hope to be able to predict what happens to a catchment after an abrupt change from a particular land use such as collectivization. The results should help improve the quality of decisions affecting the environmental and landscape management of watersheds.

Israel has long been characterized by a concern for its environment, seeking to reforest its land and maintain the purity of its inland and ocean waters even as it pursues rapid economic growth. It seems especially fitting that the strong personal ties of Israelis and East Europeans should lead to scientific cooperation to resolve the legacy of environmental problems left by the Communists.

New Crops

"The reclamation of the desert and degraded lands in Israel is one of the great ecological success stories, reversing centuries of land abuse and restoring productivity."

— *Al Gore,*
U.S. vice president

The scarcity of fresh water and the intense heat of the arid and semiarid regions of the world, where many developing countries lie, have long hampered agriculture in these lands. The shortage of water crimps the spread of agriculture. High temperatures effectively block the introduction of many important plant species that support agriculture in more temperate climates.

Many developing countries, especially those with good rainfall, have a wide range of indigenous plants that produce fruit, nuts, vegetables and other products with potential for local consumption and, in many cases, for export as high-value commodities. Some of these plants have never been domesticated. Some have never been cultivated with modern agriculture. Others have been neglected since the introduction of foreign crops and agricultural techniques during colonial times.

The unusual shape of Cucumis metuliferus, *a member of the gourd family, might make it a valuable export crop for Kenya, where a CDR team is searching for underexploited vegetables to develop for local consumption or sale abroad.*

Poor countries are facing unprecedented need to raise more food for their growing populations and to produce agricultural commodities for exports that generate foreign exchange to pay for the manufactured goods their developing economies cannot yet produce. At the same time, the demand is rising in developed countries for exotic foodstuffs such as avocadoes, kiwi fruit, macadamia nuts and domesticated Asian persimmons, which bring high prices on the international market to developing countries that export them.

Adapting Crops to Environmental Stress

Salinity of water and soil is one of the major obstacles to improving agricultural production in many developing countries. Israeli scientists, with a long history of developing salt-tolerant plants, have teamed under CDR funding with researchers in several developing countries to generate crops suitable for salty water and soil. The Philippines, for example, has about 124,000 hectares of coastal land where the salinity reduces productivity or prohibits it altogether. Israeli and Philippine scientists under CDR funding are developing salt-tolerant tomatoes, an important crop worldwide and one of the top 10 vegetable crops in the Philippines. The scientists have succeeded in developing salt-tolerant tomato lines that are expected to be used by farmers to expand food production in saline areas of the Philippines.

Another CDR team is developing salt-tolerant fodder in the coastal marshes and near other saline water sources in southern Portugal. Most water available in arid lands has some degree of salinity. In the past, salt-tolerant crops such as wheat, cotton and barley have been grown in slightly brackish water. But until the late 1970s, water with more that 0.5 percent salt content was considered unfit for irrigation. Since then scientists in Israel and elsewhere have succeeded in developing some salt-tolerant fodder species that produce good yields with undiluted seawater (average salinity of world ocean is 3.47 percent). The scientists are evaluating seven fodder species for use in the salty coastal marshes of southern Portugal, where sheep and cattle are grazed. The grazing quality of the lands could be greatly improved by growing highly productive salt-tolerant fodder and irrigating it with the saline groundwater. Preliminary results show that *Paspalum vaginatum*, a forage crop, may turn out to have the best salt tolerance and feed quality.

Israeli scientists have developed advanced physiological screening methods for selecting drought-resistant crop plants. These techniques are faster and less costly than the empirical methods commonly used and can greatly speed the development of drought-resistant plants. One screening technique, for example, was developed after the discovery that certain wheats which tend to avoid dehydration—and are therefore more drought resistant—have cooler canopy temperatures than wheats more prone to dehydration. The technique uses a vehicle-mounted infrared thermometer that can measure the canopy temperatures of hundreds of plants in a field within an hour.

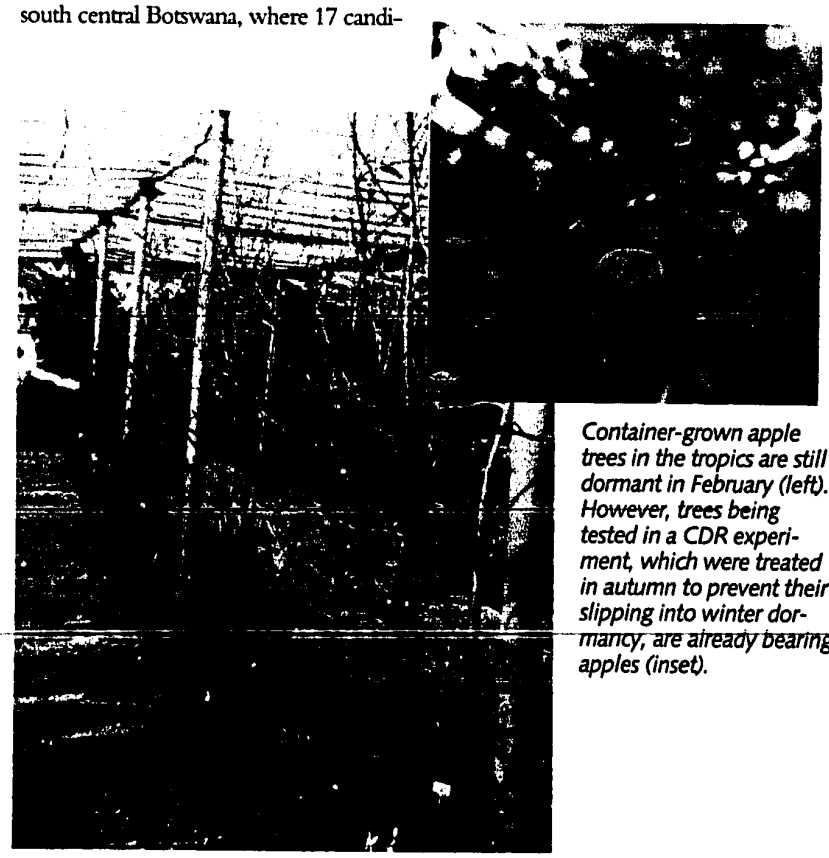
Another screening technique involves desiccating plants with a chemical to study the impact on their photosynthetic rates and nutrient uptake. Plants with a better ability to fill their grain from stem reserves of nutrients when desiccated artificially would presumably be better able to produce grain during drought. Using such methods, Israeli and Portuguese scientists screened wheat selections from both countries. They found dehydration avoidance to be the most important physiological component for drought resistance. They also selected germ plasm that can be used to improve drought resistance of wheat varieties in Portugal.

The demand for temperate-zone fruits, especially apples, is rising in the tropics. Developing countries would profit if they could grow the fruits locally rather than importing them. In temperate zones, the short days and cool temperatures help fruit trees slip into a seasonal dormancy that is ended by a winter chill which is obviously lacking in the tropics. To get around this deficiency, Israeli scientists and colleagues in Kenya are investigating methods to stimulate fruit trees, just as they start slipping into dormancy, to induce buds to break and resume growth. Initial experiments on apple and peach trees indicated that a chemical defoliant followed by an oil-based chemical treatment could be successfully used to stimulate the buds.

DEVELOPING NEW CROPS

Scientists from Israel and Botswana are looking for indigenous as well as exotic varieties of fruit and nut trees that can be developed into commercial crops for Botswana and other developing countries. Many of these fruits and nuts have high food value and high potential market value as export crops to developed countries, where the demand for new tropical fruits and nuts has been growing in recent years. The researchers established an experimental farm in south central Botswana, where 17 candidate species are initially undergoing field trial. In Israel, intensive research has begun on two promising species, yehib (*Cordeauxia edulis*) and ber (*Ziziphus mauritiana*). In a second part of the project, the scientists will screen promising species for the most salt-tolerant varieties, which will be needed for cultivation in Botswana, Israel and other arid or semiarid lands where the main sources of irrigation water are brackish or saline.

Another team of researchers from Israel and Botswana is working on the domestication of the Kalahari truffle (*Terfezia pfeilii*) in one of the more interesting efforts funded by CDR. The truffle, the edible fruiting body of a subterranean fungus, appears in rainy years throughout the Kalahari, a desert covering two-thirds of Botswana. The



Container-grown apple trees in the tropics are still dormant in February (left). However, trees being tested in a CDR experiment, which were treated in autumn to prevent their slipping into winter dormancy, are already bearing apples (inset).

BEN-GURION UNIVERSITY OF THE NEGEV

Ben-Gurion University's Zalman Aranne Central Library graces the main campus at Beer-Sheva in the Negev.

Israel is a small country, slightly larger than the state of New Jersey. Although nearly 60 percent of Israel's surface area lies in the Negev, the desert was home in 1992 to less than 10 percent of the country's population. It was the vision of Israel's first prime minister, David Ben-Gurion, to make this southern desert blossom with agriculture, industry and new communities. The university which now bears his name was established in 1969 to spearhead that vital development.

Ben-Gurion University of the Negev started with 500 students on the campus at Beer Sheva in the north of the desert. In 1976 a second campus opened at Sede Boqer, 55 km south of Beer Sheva. In a little over two decades, the university has grown to more than 7,500 students and has developed world-class capability in desert research.

"What you are doing here is vital for the entire Middle East and the world," said Egypt's President Anwar Sadat during a visit to Ben-Gurion University in 1979.

BGU scientists are contributing their expertise to the U.S.-Israel Cooperative Development Research Program (CDR) through collaboration on more than a dozen research projects with investigators in developing countries. Most of the projects are conducted by the university's two major research centers, the Institutes for Applied Research (IAR) at Beer Sheva and the Jacob Blaustein Institute for Desert Research (IDR) at Sede Boqer.

The Institutes for Applied Research—founded prior to the university, in 1957, as the Negev Institute for Arid Zone Research—is an expert at developing and adapting crops for commercial production in the Negev. It introduced jojoba (*Simmondsia chinensis*), for example, from the southwestern United States and developed many uses for the wax from jojoba seeds in the chemical and cosmetics industries; extensive jojoba plantations have already been established around the Negev. Under CDR funding, IAR scientists have teamed with researchers in Kenya, Botswana and Mexico to study a range of crops that show promise for desert cultivation, including fruits, nuts, cucurbits (gourd family), amaranths and guayule, a shrub that produces rubber.

The focus of efforts at the Institute for Desert Research is converting arid land into a productive environment. Among their specialties, IDR scientists have developed two of particular interest to CDR: water management and algae production in the desert. IDR scientists are working with colleagues in the Philippines to study the use of salt water for irrigation (Agricultural Water Resources chapter) and with investigators in Thailand and Kenya to develop methods of farming seaweed and microalgae in arid regions (Aquatic Resources chapter). In addition, scientists in other areas of Ben-Gurion University are investigating new techniques for aquaculture and new crops for the desert.

David Ben-Gurion, namesake of the university, moved to the Negev when he left the office of prime minister of Israel. It was his belief that the desert is critical to the future of his people. Said Avishay Braverman, the current university president: "An Israel with a developed, flourishing Negev will be a healthier, more secure Israel, able to share the benefits of her technology and achievements with all of her neighbors."

truffle is an important source of food and revenue for desert dwellers, who earn cash income by selling surplus truffles in town markets. Domesticated, the truffle could be a useful crop for other desert countries, perhaps even generating export income for areas with few other commercial opportunities. In Botswana, 80 percent of the people live in rural areas, where only 5 percent have gainful employment. Researchers in Israel, working on cultivation of a related truffle there, have joined with colleagues in Botswana to investigate the Kalahari truffle, identify its symbiont plant and explore methods to cultivate the truffle.

In another project, CDR researchers are looking in Kenya for indigenous vegetables that can be developed for local consumption or for worldwide export. Vegetables are valuable sources of vitamins and minerals, but vegetable consumption in Africa is less than one-third that in developed countries, even though hundreds of suitable species are available. During colonial times, little was done to develop vegetables in tropical and southern Africa. Now many African countries import fresh vegetables, but often at a price too high for much of the population. A team of Israeli and Kenyan investigators is searching Kenya for edible cucurbits (gourd vegetables) and amaranths (leaf vegetables). The more promising varieties will be developed through breeding programs and agromanagement practices that improve crop yields under local conditions. The interesting shapes and unusual colors of many cucurbits make them potentially valuable as ornamental fruits for export to Europe, North America and elsewhere. In addition, the survey and collection of germplasm of primitive species may uncover new genetic sources for breeding crops that are resistant to disease and pests and that produce higher yields faster. Traditionally grown cucurbits, in particular, are disappearing fast from Africa, and the germplasm collection will be important for maintaining this valuable genetic resource.

At a nursery in Botswana, investigator Benjamin Lebodoi grafts selected plant material during a CDR project to identify and investigate fruit and nut trees that can be developed into commercial crops for developing countries.

Another plant with the potential to boost agricultural economies in developing countries is guayule (*Parthenium argentatum*), a shrub native to the Chihuahua desert of northern Mexico. The rubber extracted from guayule is quite similar to that derived from the rubber tree *Hevea braziliensis*, a chief source of natural rubber. Guayule latex has not been exploited as a rubber source since the rubber crisis in World War II, in part, because its polymeric chains do not have the functional chemical groups like those on hevea rubber that allow it to be chemically modified. With CDR funding, Israeli and Mexican researchers have set out to chemically modify guayule rubber so that it will yield materials with desirable chemical, thermal and mechanical properties. With the creation of such products, the potential of guayule as a cash crop for semiarid lands could become a reality.

Improving Indigenous Crops

CDR crop development efforts also aim to improve indigenous crops that have not yet benefited from the advances of modern agriculture. Sesame, for instance, is an important oil crop grown almost exclusively in developing countries. One of the obstacles to expanding sesame production has been the indeterminate nature of cereals: they ripen at different times, depending on moisture and other factors. Thus, at the time fixed for harvest, some seed capsules are immature while others are very mature. Consequently, many seed capsules shatter and lose their seeds before fields are ready for harvest.

With CDR funding, Israeli and Thai scientists have undertaken the improvement of sesame breeding lines, basing their work in part on a mutant variety

Pouteria caimito *(Sapotaceae), a sweet, juicy fruit known as abio to the Quicha tribe in eastern Ecuador, is one of the edible plants identified by a CDR team searching for indigenous plants that local tribes can develop to boost their economy and preserve their way of life.*

developed in Israel that is determinate: all seeds ripen at a fixed, predictable time. The scientists are also trying to develop varieties with capsules that do not shatter easily, so that the crop can be harvested by combine. Once these strains are developed, it should become economical for farmers to use fertilizers and other costly inputs that will further increase yields and profits.

In Portugal, another team of Israeli and local scientists is attempting to boost carob production. Carob pods have been used for animal feed, occasionally for human consumption and for various other uses in Mediterranean countries since ancient times. In recent years, the market for carob pods has been expanding along with its uses in pharmaceutical products, animal feeds and human foods, especially as a substitute or extender for chocolate and cocoa. The gum extracted from carob seeds is commercially valuable and is used as an emulsion stabilizer and thickener in ice creams, cheeses, soups and salad dressing.

The Israeli-Portuguese team is investigating the role of nitrate in carob not only as a nitrogen source but primarily as a regulatory element in the transport of nutrients through the plant. This knowledge will provide the basis for increasing the efficiency of nitrogen fertilization and irrigation. The resulting improved agromanagement techniques for carob production might also be used with other tree crops.

The development of indigenous plants and crops may mean more than a boost to an agricultural economy in a developing country; it might also help preserve the way of life of peoples threatened with "ethnocide" by approaching development. In Ecuador, the most densely populated country of South America, the government encourages settlers to move into the sparsely settled Amazon region. The new roads, oil fields, plantations and settlements, however, threaten the cultural identity of the Indians who live by gathering plants for food and medicine and, sometimes, by practicing transitional farming nearing hunting areas.

Scientists in Israel, Ecuador and the United States plan to help these Indian tribes preserve their way of life by identifying and domesticating their most valuable food and medicinal plants. This should improve the Indians' economy, fortify their identity and, in the long run, contribute to a healthier, more pluralistic society in Ecuador. This approach might also be extended to other countries such as Colombia, Bolivia or Peru, where development threatens to extinguish indigenous cultures. In addition, the identification of new potentially valuable plants may contribute to the local agricultural and pharmaceutical industries. Interviews with Indians knowledgeable about local plants have already led to the collection of about 40 species of food plants and 100 species of medicinal plants used for diarrhea, bleeding, snakebite, sprains, parasites, nervous disorders, contraception and other applications. Researchers are helping indigenous groups learn to cultivate the most promising species in greenhouses and then replant them outside. By managing the growth of these plants, it will be possible to increase the efficiency of future gathering efforts and protect the useful varieties from being lost through overcollection.

Many developing countries have the climate and genetic resources to develop food crops for local consumption and export. The Israeli scientific community, with its history of success in bringing new crops to arid lands, has the expertise that can speed that development process. Through CDR, this marriage of resources and expertise is making deserts bloom around the globe.

Aquatic Resources

"Raising fish in the desert is not as paradoxical as it sounds."

— brochure published by Ben-Gurion University of the Negev

Many developing countries have aquatic resources with the potential to produce food and new raw materials for local and international markets. Some have the lakes and rivers with potential for freshwater aquaculture, many have the saline or brackish water suited to mariculture (aquaculture of marine organisms), and most have the long days of intense sunshine that stimulate the growth of seaweed and microalgae.

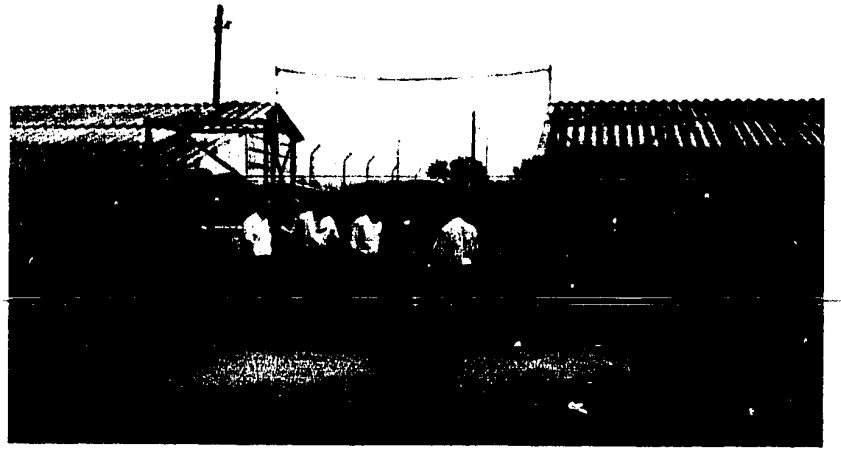
Many of CDR's aquatic-resource projects aim to boost the output of aquaculture systems. Several projects focus on developing better or more cost-effective fish feeds. Others aim at developing algal strains that produce high-value products. Algae have long been a source of products needed by the food, pharmaceutical and biotechnology industries. Wild seaweed harvested from shallow coastal waters has supplied many of these needs in the past. But pollution and overexploitation have greatly reduced the wild sources of seaweed, creating a need for the scientific management of algae production.

Improved Algae Production

CDR is funding several projects that investigate the aquaculture of seaweed, or macroalgae. In recent years demand has been increasing for macroalgae extracts—agar, algin and carrageenan—used as suspending, thickening, stabilizing and gelling agents in food, paper and textile production. Agar also is used in culture media for microbiological applications. The world market for these products is currently about half a billion dollars per year, and the demand is rising.

Investigators in Israel and Haiti are developing a system to grow seaweed on sand, irrigate with salt water and extract the crop's valuable substances. The CDR-funded portion of the project focuses on selecting a suitable variety of seaweed and developing a spray irrigation system to support rapid growth. The ultimate goal is to integrate the seaweed farm with on-site plants for extracting phycocolloids and for treating the waste materials through anaerobic digestion to produce valuable by-products such as methane gas, which can be converted to electricity.

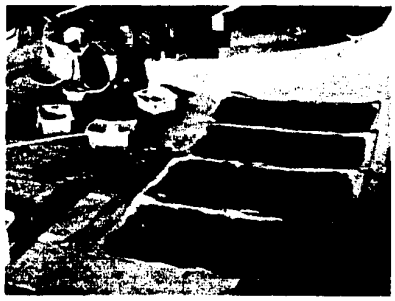
Investigator Ami Ben-Amotz sweeps the bottom of large-scale ponds used in Israel for the intensive production of Dunaliella bardawil, *a microalga rich in beta-carotene. In a CDR project with Thailand, investigators are exploring ways to boost the aquaculture production of this valuable substance.*

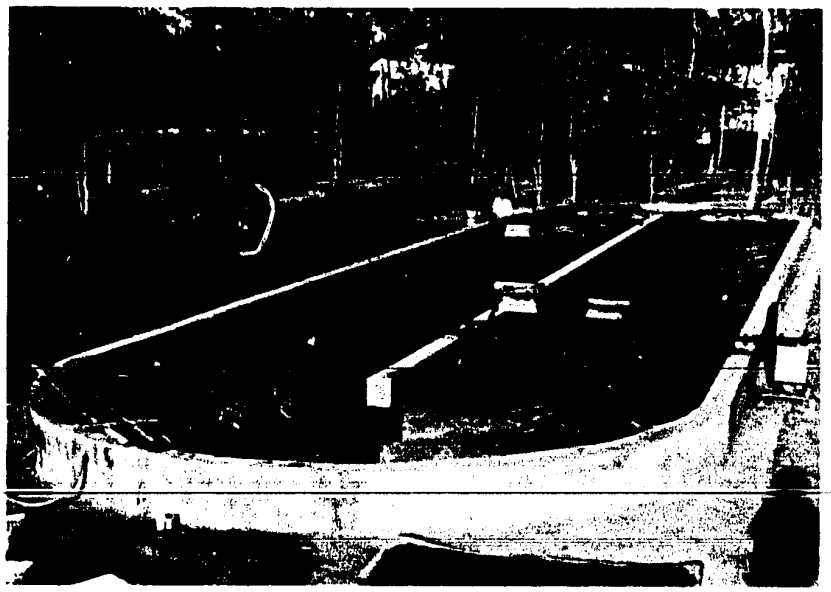


Investigators in Israel try out the sprayers of a saline-water irrigation system before shipping it to Haiti for field trials in a CDR project to develop methods for growing seaweed on sand and extracting valuable substances from the crop.

Microalgae also hold great potential as a valuable source of proteins, lipids, starch, natural pigments and biopolymers that can be used in food, feed and chemicals. Microalgae have scarcely been exploited, even though algal culture ponds produce five to 10 times more biomass per acre than conventional agriculture. Algal culture appears to be particularly well suited to those developing countries with abundant saline water and sunshine, in which microalgae thrive.

Only a few countries are producing spirulina (*Spirulina*), a blue-green filamentous alga that was being harvested and eaten as a primary protein source by the Aztecs when the Spanish conquistadors arrived in Mexico in the 16th century. During the 1970s, spirulina became popular as a health food rich in protein and vitamins. Today it retains a niche in the health-food market. But expansion of the spirulina industry into other markets has been limited by lack of the knowledge about pirulina cultivation that could bring down production costs. Israeli and Thai scientists under CDR funding are looking for the best spirulina to use in pond cultivation of microalgae. The most promising strains collected will be evaluated for optimal production characteristics—resistance to photooxidation, salt tolerance, long filaments, floating ability and chemical composition. Finally, two different culturing techniques will be developed for the selected strains. One will be a simple, low-cost, minimal-energy pond reactor that produces modest yields but can be operated by unskilled workers. The other will be an advanced pond reactor that uses sophisticated mechanical and control devices requiring skilled operators to produce higher yields. These systems can be easily adapted to various levels of operator skills and other local conditions.



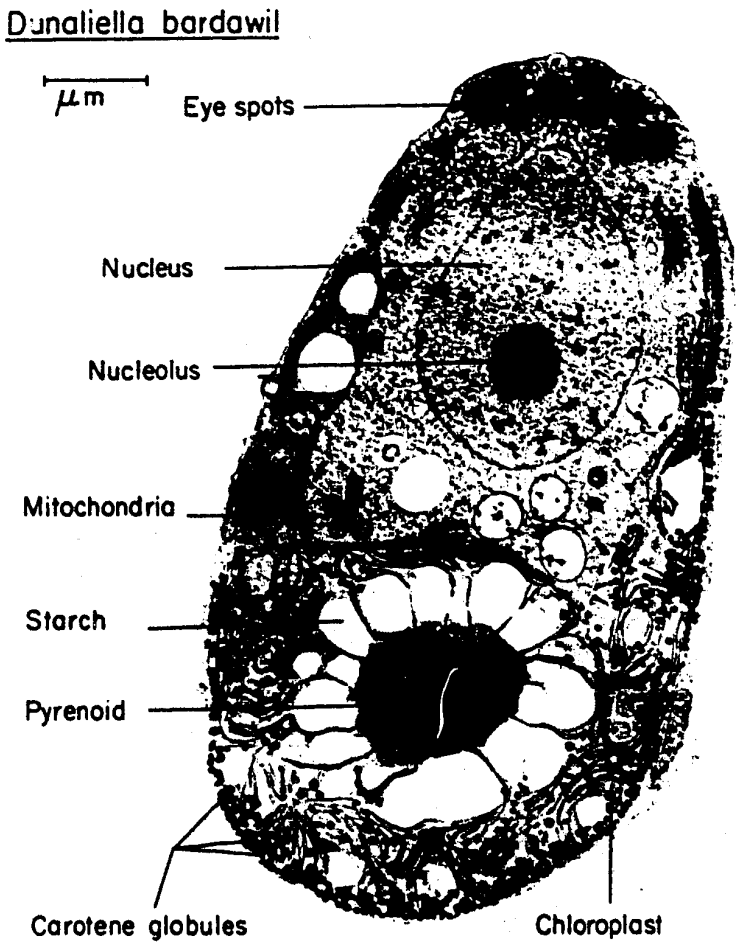


In Thailand, CDR investigators demonstrate aquaculture techniques (bottom) developed for producing spirulina, a blue-green alga with expanding commercial potential. A worker (top) spreads the wet spirulina biomass for drying.

In addition to sources of low-cost products such as protein, microalgae have the potential to produce high-value products. The export of these products would boost the economies of developing countries that have the sea water and desert land that can be converted to microalgae production. In follow-on work to the spirulina project, Israeli and Thai scientists are studying different microalgal species and culture conditions for producing eicosapentaenoic acid (EPA), a polyunsaturated fatty acid that is effective in reducing the risk of heart disease and preventing, or even reversing, the formation of the plaque that causes atherosclerosis (clogging of arteries).

The market for EPA is estimated at several hundred million dollars per year and is expanding rapidly. EPA has been available in products made from fish oils. But for several reasons, that source has been unsatisfactory. Large-scale microalgae cultivation for producing EPA has never been tested. The CDR scientists are investigating several algal species for EPA production and exploring methods for optimal production. One novel idea being pursued is a cost-effective method for harvesting *Porphyridium*, a red microalga containing EPA, based on a pH-dependent autoflocculation (aggregation of the algae into a mass).

In another follow-on project to produce a high-value product, Israeli and Thai investigators are studying the microalga *Dunaliella bardawil*, one of the richest sources of natural beta-carotene known. Under optimal growing conditions, *Dunaliella* can be induced to produce beta-carotene up to 13 percent of their dry weight. Other algae generally produce no more than 0.5 percent. Beta-carotene is a precursor to vitamin A, as well as a food coloring. Synthetic pig-



Globules of beta-carotene show up as black dots on this electron micrograph of Dunaliella bardawil. *CDR researchers are investigating better ways to grow this beta-carotene–rich microalga, which could be produced by developing countries suited to aquaculture production.*

ments for use in animal and human foods are prohibited now in many countries, so the demand for natural food colorings has been rising. In this CDR project, the investigators are developing methods of producing beta-carotene–rich algae to supplement the diets of fish, shrimp and other aquatic organisms. It would boost nutrition and add an attractive color to fish which, in turn, would probably command a higher market price than white fish. The knowledge created by the research may lead to a practical, natural pigmentation approach for enhancing the coloration of seafood. That approach might evolve into another source of income for developing countries with the natural conditions for aquaculture production.

BETTER SEAFOOD PRODUCTION

In the area of seafood production, a CDR project in Ecuador is attempting to solve a problem that is holding back the expansion of shrimp production in that country. The aquaculture of shrimp has become the largest nonpetroleum earner of foreign currency for Ecuador. Shrimp farming produced about $400 million worth of shrimp in 1986 and provided around 140,000 jobs. But the most important shrimp variety, *Penaeus vannamei*, has never been fully domesticated. Shrimp farms have been stocked with larvae from the wild, but that source has been seasonal and inconsistent. At times, 40 to 50 percent of shrimp ponds have been idle for lack of shrimp larvae. Previous efforts to get the female to produce larvae in captivity have not been very successful, owing to the failure of gonad maturation in artificial habitats.

Under a CDR grant, Israeli and Ecuadoran investigators are exploring ways to induce ovary maturation in the female shrimp by stimulating it with hormones from continuously fecund females of the prawn *Macrobrachium rosenbergii*. Research has shown that hormones from one crustacean species can be active in another. In addition, the evolutionary closeness of these two species increases the chances for successful cross-reactivity of the prawn hormones in the shrimp.

A major requirement for aquaculture in developing countries is getting enough good feed. There is particular need for dependable, inexpensive supplies of feed for fish hatcheries, where fast-growing newly hatched larvae continually change diets to larger food items. In one CDR project, Israeli and Philippine scientists are seeking the best strain of the rotifer *Brachionus plicatilis*, a microscopic aquatic invertebrate animal, to raise as feed for newly hatched marine fish larvae. Rotifers are excellent feed for the larvae during the larvae's first critical days of life. But the inability to provide enough rotifers at crucial times has been a bottleneck in mariculture hatcheries. The CDR investigators are searching for the best rotifer strain to use in a semicontinuous mass culture system adapted for the Philippines. They are developing the use of enzyme

DOING SCIENCE THE HARD WAY

Scientists in developing countries face obstacles to their work that require exceptional dedication and, sometimes, heroism to overcome. Material shortages of drastic proportions, poor communication systems and danger from political unrest must often be handled before scientists can turn to their research. CDR is designed to resolve some of these problems and must live with others, such as political unrest, that are beyond the program's control. Some of the problems CDR investigators face are chronicled in their periodic reports to the USAID Office of Research in Washington and by visitors to CDR host countries.

Material shortages plague many developing-country scientists. CDR investigators working on a saline irrigation project in Peru, for example, reported that "the last car of the department ... responsible for our research was finally, a few months ago, broken down." In addition, they were still waiting after seven months for a replacement part for the single flame photometer at the university so they could do potassium and sodium tests.

In the former Soviet Union, where CDR is becoming involved on a limited basis (see sidebar, page 36), a shortage of heating fuel has kept some scientists in Georgia out of their labs. "It's very cold, we have no heat. We can't make people work under these conditions," lab directors told Jill Conley, a member of a U.S.-Israel delegation there to discuss financial assistance through USAID's CDR and CDP programs (see sidebar, page 37). Conley, who toured several laboratories, also noted that most of their equipment was decades behind that found in labs in Western countries and even some developing countries.

Training and retention of scientists and technicians are also endemic problems in countries with little hard currency. Conley said that in Kazakhstan, for example, the inability to get top-notch training probably contributes to the variable quality of the research she observed there. "Some institutions would have folks there who were trained in Moscow, and others didn't have the opportunity to leave the region."

Technicians prepare a survey point in an elaborate network aimed at evaluating erosion and deposition of seasonal streams in Botswana. Investigators in developing countries often have difficulty attracting and retaining good technicians.

Scientists elsewhere pointed to a shortage of funds to keep trained personnel on their research teams. A CDR scientist in Thailand reported no progress on the planned development of a special electronic hydrometer for a solar pond experiment because "the responsible research assistant left the project to join a private firm for a higher salary." The principal scientist on a CDR investigation in Botswana complained of similar problems: "The project has encountered great difficulties in attracting a suitable university graduate for work as a research assistant/associate," the investigator reported. They "are much keener to accept work which offers permanence. Even the Government (department cooperating on the project) ... is losing personnel in favor of private companies."

Communication with scientists in developing countries is also a major difficulty. An Israeli scientist on a CDR project reported having lost touch with a colleague in Senegal for more than a year. "Without an uninterrupted channel of communication," the Israeli wrote to Washington, "we cannot accomplish the field work."

Conley observed other communication problems in the former Soviet Union. "Fax communication is very difficult, and, for the most part, telephone communication to some of the countries is very hard," she said. In addition, fuel shortages delayed her plane departure from Georgia, but she felt lucky to leave after only three days. "Another American who was there at the same time we were said it took him 10 days to get out the last time."

Political unrest slows or blocks science in more than a few countries around the world. Scud missiles and suspended airline service disrupted research in Israel in 1991 during the Gulf War, which contributed to the cancellation of research field trips by at least one CDR investigator. CDR scientists working on a project involving sand culture with saline irrigation in Peru reported delays in their work due in part to the unstable political situation there. And a CDR researcher from Ghana, on appointment as a professor at the University of Liberia, was completely cut off from the outside world for about six months during the violence in that country in 1990, forcing the postponement of field work on the project. His Israeli colleague later reported that the "professor ... managed to escape from Liberia to Ghana at the end of 1990, happily without any mishap."

It is clear that scientists need help in building the research capacity of their labs so they can work in these circumstances. That they can be scientifically productive while overcoming such constraints is remarkable.

Investigator Amir Sagi examines freshwater prawns that produce a hormone which may stimulate gonad maturation in saltwater shrimp. If so, knowledge gained in this CDR project with Ecuador could boost shrimp production there and in other developing countries suited to aquaculture.

markers to monitor the purity of the culture so that inferior strains, which easily contaminate a system, can be eliminated. In addition, they are investigating factors, such as water temperature and salinity, for their effects on rotifer reproduction capacity. Initial work has already found two Philippine rotifer strains that reach very high production rates when cultured at relatively high temperatures. After selecting the optimal strain, the team plans to incorporate it into a semicontinuous system that produces relatively high densities of at least 200 to 500 rotifers per mL^{-1}.

Live foods, such as rotifers and copepods, are currently expensive to raise, and the supply is unreliable if they are harvested from the ocean. A major difficulty with current processed feeds is that they quickly sink to the bottom of rearing containers, where they are lost as feed and foul the water. Portuguese and Israeli scientists are therefore developing a processed feed that overcomes these problems. The goal is to encapsulate a nutritious formulation in a tiny protective envelope of polymers that will be buoyant and attract fish. The team has already tested a number of these microencapsulated feeds and hopes to eventually have one that is as nutritious and attractive to fish larvae as live foods.

Agricultural residues, such as manure and fiber left from grain crops, have been successfully converted by microorganisms into inexpensive sources of natural foods for aquaculture in freshwater ponds. Mariculture ponds, however, have been less than half as productive as freshwater ponds. Salt water contains more sulfate, which is apparently converted into toxic sulfide as a by-product of the microbial processing of organic matter. Israeli and Philippine scientists suggest that sulfide accumulations may limit the availability of natural foods in mariculture ponds. Using new stable-isotope technology, the scientists are seeking to find out exactly which foods in a pond are actually consumed by the fish. The researchers can then investigate the influence of sulfate-sulfide microbial reactions on the processing of sediment organic material into these natural foods. With this information, the scientists can design a management strategy to improve fish production while reducing reliance on refined fish feeds.

Modifying an aquatic ecosystem has the potential to cause considerable environmental damage. Israel, however, has sought to combine environmental concerns with its efforts to exploit aquatic resources such as Lake Kinneret (Sea of Galilee). This experience provided the basis for a CDR project to investigate the feeding habits and food availability of tilapia (*Tilapia*), a commercially valuable fish, in Lake Victoria, Africa's largest lake. The introduction of the Nile perch (*Lates nilotiens*) and several cichlid species plus the less-than-optimal regulation of fishing operations in recent years has damaged the tilapia and other native fish populations of the lake. Shallow waters were overfished, deep waters were underused and the structure of the fish population was altered with repercussions in other parts of the ecosystem. The Kenyan and Israeli investigators studied tilapia and plankton, its main food source, as well as conditions in the lake, to provide the scientific information needed to improve fishery management and promote the recovery and conservation of the natural fish populations. The information will be useful to fishery managers in Kenya, Uganda and Tanzania, which all border Lake Victoria.

These small projects can each help developing countries to advance in small-scale aquaculture and mariculture systems. In some cases the results will be direct food production for the developing country. More typically the research is aimed at employment generation and the development of new or improved export products. In developing countries, as in the United States, it is sometimes more cost-effective to create jobs and income through many innovative small enterprises than through a few large enterprises.

Pest Control

"There have always been periods of time and geographical areas in which people were plagued by drought, famine and food shortage. Today, these problems ... affect almost exclusively the developing nations of the world."

— Scopus, magazine published by Hebrew University of Jerusalem

Modern chemical pest control, based on the use of potent synthetic pesticides, has been extraordinarily effective at eliminating insects, weeds and other noxious pests. It thus has become the standard means of pest control throughout much of the world. But chemical pesticides are increasingly expensive and beyond the reach of many in developing countries. Their widespread use has wiped out the natural enemies of many pests, eliminating nature's means of control, and has led to the emergence of chemical-resistant pests that are often more harmful and difficult to control than their predecessors. In addition, synthetic chemical pesticides are sometimes toxic to humans, plants and animals, and they have too often contaminated soil and water and polluted the environment generally.

Consequently, many people are expanding the range of pest control measures, often seeking to integrate chemical and biological approaches into effective, affordable and environmentally benign packages. CDR is funding innovative research both on new biocontrol techniques and on the integration of biocontrol techniques with standard chemical control methods.

New Biocontrol Techniques

Bee colonies in most parts of the world except Australia are facing infestation with the varroa bee mite (*Varroa jacobsoni*), a devastating parasite that in some countries has destroyed colonies, reduced honey production and threatened pollination. Although its natural host is the Asian honeybee (*Apis cerana*), the mite spread to the larger European honeybee (*A. mellifera*). The grooming behavior of the Asian honeybee has made it largely resistant to the varroa mite; however, its European relative, now the major honey producer in Thailand and worldwide, does not have this protective behavior. Beekeepers have managed to maintain colonies of European honey bees by using various types of mite control, including chemical pesticides. But most chemical treatments are expensive, marginally successful and also harmful to honeybees.

Investigator Eli Shaaya mixes an edible plant oil with wheat to learn whether the oil protects the grain from insects during storage. This CDR project with Thailand is investigating oils that might protect stored seeds from infestation.

Technicians count dead mites during a CDR project to test whether Asian honey bees, whose grooming habits protect them from the mites, will also groom European honey bees, which have been devastated by the mites. Photo (left) shows one bee grooming another.

In Thailand, a CDR project has taken advantage of the natural resistance of *A. cerana* to devise a method for controlling the varroa mite. In studying the grooming behavior of the two bee species, the investigators have found that young Asian honeybees will groom the mites from the European honeybees if the two species are raised in the same colony. Earlier studies indicate that young Asian honeybees will not be rejected by the European honeybee colony. The scientists are now developing methods to artificially inseminate and mass rear Asian honeybee queens to produce Asian honeybees for use as biocontrol agents in colonies of European bees.

Corn plot devastated by the African armyworm had to be replanted, whereas nearby corn sprayed with a new strain of Bacillus thuringiensis, *isolated in conjunction with a CDR project in Kenya, remained essentially untouched by the infestation.*

Periodically, outbreaks of the voracious African armyworm (*Spodoptera exempta*) occur in Africa, around Zimbabwe and Mozambique. Winds carry the moth north and south, where secondary outbreaks cause great losses to grasslands and cereal crops such as corn, rice, oat, rye, barley, sorghum and millet. During one week-long infestation covering 65 square kilometers in Kenya, for example, armyworms devoured an estimated 50 tons (dry weight) of herbage per day. Using chemical pesticides on the armyworm is risky because many of the fields are close to housing and often have animals feeding in them. To find a better control agent, Israeli and Kenyan scientists using funds from CDR screened many strains of the bacterium *Bacillus thuringiensis* (Bt) isolated from soils in Israel and Kenya and from stock cultures. They found several isolates with significant insecticidal activity against the army worm as well as some that are active against a related pest, the Egyptian cotton leafworm (*Spodoptera littoralis*). The scientists also showed that spraying Bt preparations in fields was effective in varying degrees at controlling the larvae. The best isolates may be considered for large-scale production as biocontrol agents against these two pests.

CDR investigators release tiny wasp larvae (parasitoids), natural enemies of the whitefly that carries a virus which attacks cassava, in a field in Malawi. Several CDR projects focus on using natural enemies to control pests.

Insects can function as pests not only by eating plants but also by carrying diseases that contaminate crops. In a CDR project with Malawi, researchers hope to combat cassava mosaic virus by controlling its host, the sweet potato whitefly (*Bemisia tabaci*). An infestation

AGRICULTURAL RESEARCH ORGANIZATION, ISRAEL

In Israel, farmers produce enough fruits, vegetables and flowers for domestic and export markets to pay for all the agricultural products consumed by the country, despite being handicapped by a shortage of water. Much of this success can be traced to the efforts of the Agricultural Research Organization (ARO), Israel's oldest scientific institute and a frequent participant in CDR projects. The ARO, for instance,

- produced the first citrus plants ever to be grown from single cells of one desirable plant;
- bred and introduced high-yielding dwarf fruit trees that can be mechanically harvested at ground level;
- introduced temperate-zone fruits – pear, apple, peach, apricot, nectarine, plum, cherry, and blueberry to Israeli agriculture;
- paved the way for agricultural settlements in the lower Jordan Valley by demonstrating how to leach salt from the soil by repeated flooding; and
- showed how cold winter air could be forced into grain silos to inhibit mold and insect growth well into summer.

Much of ARO research takes place at the Volcani Center, named for Itzhak Elazari-Volcani, who founded in Palestine in 1921 an agricultural experiment station that became the ARO. The Volcani Center is on the main ARO campus at Bet Dagan in central Israel. Research is also conducted at two other major experiment stations, one in the north and another in the south, and a dozen smaller ARO experimental farms.

"Our mission is the same as when we began: to further Israel's agricultural potential by the use of scientific research," said Joseph Shalhevet, director of the Agricultural Research Organization. "Agricultural production is efficient in Israel because farmers here have always been eager to try out in their fields innovations based on scientific research."

CDR draws heavily on ARO expertise in pest control and water resource management and to a lesser extent in other areas of agriculture.

Since the early 1970s, ARO has studied the protection of crops through the use of insect traps baited with synthetic sex pheromones. Pheromones are chemicals that insects (and animals) use to communicate with others of their species. Pheromone-baited monitoring traps scattered throughout fields can alert farmers to precisely where and when to apply insecticides, thus reducing pesticide use to the minimum. Such monitor/control trap systems are used against cotton leafworm and bollworm, tomato looper, potato tuber moth, corn borer, grape moth, apple coddling moth and other pests. A mass-trap system designed by ARO can control citrus flower moth well enough to totally eliminate the need for insecticide. With CDR, ARO is participating in pest control projects investigating the use of sex pheromones to trap cotton bollworms in Thailand and elsewhere, the use of traps baited with colored material to control whiteflies, and a number of other pest control strategies (this chapter).

ARO has also gained valuable expertise investigating agricultural problems related to water resource management, including ways to improve irrigation and the use of rain water. The organization has designed schemes for fertigation—nutrients delivered via drip irrigation—that allow cultivation of vegetables in sand dunes and citrus trees in eroded, shallow, hillside soils. It is involved with CDR projects to evaluate new irrigation techniques for crops grown in Swaziland, to use refinery waste products to seal irrigation ditches in the Philippines and to develop methods to take better advantage of the little rain water that does fall in arid and semiarid lands (Chapter 1).

"Of course, research for agriculture cannot be confined to national borders," Shalhevet said. "Our continuing research provides renewable means of livelihood not only to Israel but to less fortunate countries where food self-sufficiency is still far off."

The main campus of the Agricultural Research Organization at Bet Dagan in central Israel is home to the Volcani Center and ARO headquarters.

of the virus can reduce the cassava production by as much as 75 percent. The CDR scientists are investigating a number of parasitoids (in this case, tiny wasp larvae that ultimately kill the host) that live only in an Aleyrodid (whitefly) host and that could be safely introduced to Malawi. In addition, the researchers are developing whitefly traps, baited with yellow straw or other material that attracts the whiteflies. The scientists expect that by trapping large numbers of whitefly adults, the whitefly populations can be kept low enough for them to be effectively controlled by the parasitoids.

*Laboratory technician Nadia Nemny checks larvae of Egyptian cotton leafworm [*Spodoptera littoralis *(Boisduval)] for mortality or insect growth regulating effects after larvae fed on leaves sprayed with an experimental formulation of neem, a substance derived from the Indian lilac tree. This CDR study seeks to improve neem's natural insecticidal properties.*

INTEGRATED PEST MANAGEMENT

Parasites have been used to control scale insect pests in citrus crops around the world. But the continued use of broad-scale pesticides has largely blocked the increased use of natural enemies in integrated pest management schemes, which combine natural and chemical control methods. The insecticides have been killing the beneficial insects as well as the pests. The schemes would work, however, if the beneficial insects were resistant to the pesticides. In the Philippines, CDR researchers used conventional and novel methods to select species of *Aphytis* (parasitic wasp)—the most effective parasites against citrus scale insects—for resistance to pesticides used on citrus in Israel and the Philippines. Among their findings the scientists discovered a population of *A. lingnanensis* Compere parasitizing California red scale [*Aonidiella aurantii* (Maskell)] in a citron (lemonlike fruit) orchard that had received heavy pesticide applications. The parasite was much more resistant than other species to the insecticide azinphosmethyl and somewhat more resistant to permethrin. The parasite could thus be used with these agents in an integrated approach to scale control with reduced amounts of insecticide.

In another approach to integrated pest management, a CDR group involving Thailand investigated recently discovered protective substances—epicuticular plant surface agglutinins (EPSAs)—secreted by some plants to the waxy outer layer covering their surfaces. Preliminary lab tests in Israel indicated that EPSAs may be involved in protecting plants from fungi, viruses and other pathogens. In addition, EPSAs seem able to neutralize harmful oxidants from natural and human-made sources such as ozone, industrial pollutants and the herbicide paraquat (methylviologen). The scientists speculated that seeds treated with EPSA protectants might yield seedlings tolerant to pollution stresses or to paraquat. In the latter case, more effective doses of the herbicide could be used on a field without harming the crop. The scientists screened EPSAs in cucumber, rice and other economically important crops and found that EPSA, indeed, inhibits germination and development of some pathogenic fungi on these plants.

Natural Substances for Pest Control

Insect pests can, in effect, provide their own biocontrol agents through the use of their pheromones, substances which provide chemical communication within a species. A CDR group involving Thai scientists is working on ways to monitor and control the cotton bollworm (*Heliothis armigera*), a pest widespread through Asia, Africa, Europe and Australia. Little was known about the role of pheromones and the sexual behavior of *H. armigera*. So the CDR scientists have undertaken a systematic study of its pheromones and sexual behavior with the aim of developing pheromone-baited traps to monitor insect populations and devising a control strategy. One pheromone-based strategy, trapping males, has proved effective against a selected species—the American bollworm (*Heliothis zea*). Perhaps a more promising method is to formulate pheromones and release them under conditions that will disrupt mating of the pests.

In their evolutionary battle against pests, many plants have evolved to produce potent insecticidal substances. Some of these natural products have been used as a "poor man's insecticide" primarily by individual farmers in Africa and Asia. For example, the neem, or Indian lilac (*Azadirachta indica* A. Juss.), is a tree whose seed kernels yield insecticidal substances that are used widely in many developing countries. Its standard oil and extracts are harmless to mammals. Neem extracts, however, rapidly decompose in the field due to ultraviolet radiation and oxidation. A CDR project with researchers in Thailand is therefore exploring ways to prolong or improve the insecticidal potency of neem products through formulations with ultraviolet protectants and antioxidants as well as with synergists, substances that would boost the effect of neem's insecticidal properties.

In warm climates, from 10 to 40 percent of stored crops is often lost to insects. The massive use of chemical insecticides has resulted in resistant insect strains. Moreover, health concerns have led to restrictions on the acceptable levels of insecticidal chemical residues in foods. A group of Israeli and Thai investigators is investigating several plant oils that might be safely used to prevent insect damage to stored grains and legume seeds. Early laboratory data show that a low concentration of crude palm-kernel oil is a good protectant against Bruchid beetle attacks on legume seeds. Crude soybean oil is relatively effective against damage by *Sitophilus* (weevil) species to wheat and corn. These oils will now be tested in field experiments.

Plant pests of many kinds continue to plague developing countries, reducing their agricultural production and holding back development generally. CDR, through the investigation of biocontrol techniques, natural substances and integrated pest management schemes, is helping overcome such infestation in ways that are cost-effective, harmless to humans and safe for the environment.

Seeds in the lower jar were treated with an edible plant oil to protect them from insects in this CDR project with Thailand. Investigator Eli Shaaya and a technician examine untreated seeds in the upper jar, which show signs of insect damage.

Human Health

"The health of a people is really the foundation upon which all their happiness and all their powers as a state depend."

— *Benjamin Disraeli, British prime minister*

In the tropics malaria is a resurgent scourge, the most serious and prevalent single disease in human history. The continuing development and spread of drug-resistant malarial strains and insecticide-resistant *Anopheles* mosquitoes have contributed to the resurgence of malaria. Leishmaniasis, another parasitic disease that is spread by sand flies, is also a widespread problem in many tropical and subtropical developing countries. Its visceral form, kala-azar, is an epidemic killer. Trypanosomiasis, caused by a parasite carried by the tsetse fly, plagues Africa by afflicting people as well as cattle. In humans, the disease is known as sleeping sickness. CDR research focuses on these and other human diseases.

In Kenya, investigator Jim Kagai works with blood samples taken from filariasis patients in Coast Province. Microfilarial worms are separated from the samples for use in a CDR project that is developing better diagnostic tools for this disease.

MALARIA

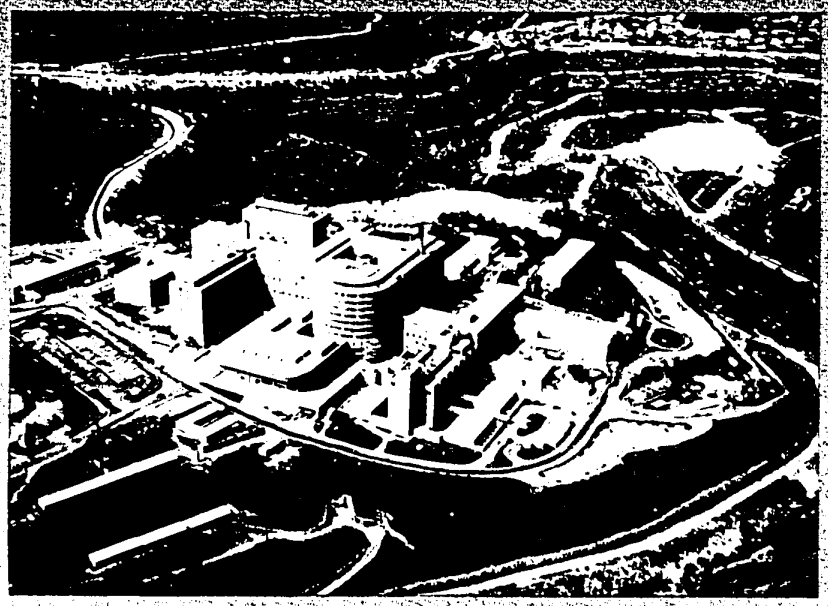
CDR is investing significantly in the effort to control malaria, the most important disease in the tropics. Worldwide, about 7 million new cases are officially reported each year, but the true incidence is estimated at more than 200 million. In Africa alone, malaria is believed to kill at least 1 million infants each year.

New drugs are desperately needed to treat malaria. Drug-resistant strains of the most serious malaria protozoan, *Plasmodium falciparum*, have appeared widely, rendering the previous drug of choice (chloroquine) practically useless in many areas. Falciparum malaria causes chills, fever, sweating and, in some cases, delirium and coma. More than 10 percent of untreated falciparum malaria cases end in death.

Because of the functional similarity in the quinine family of antimalarial drugs, malaria parasite resistance to one quinine derivation often confers resistance against others. New drugs based on different mechanisms are needed. A CDR project with Thailand is investigating a novel approach to drug development based on a peculiarity of the parasite's metabolism. Researchers noticed that the parasite gathers large amounts of iron in its digestive vacuole while living in the host erythrocyte (red blood cell). The CDR scientists propose to attack the parasite by using a new class of chelators (metal scavengers) that would bind to the iron in the parasite's vacuole and, in the process, form chemical agents (free radicals) that would kill the parasite. If indeed their theory holds true, the information could be used by the pharmaceutical industry to develop and market a new class of drugs that would be effective against *P. falciparum* strains, possibly even those resistant to chloroquine.

Another CDR project with Thailand is investigating ways to starve or poison the malaria parasite by controlling passage of material through the membrane of the parasitized erythrocyte. Studies have already shown that after a parasite enters an erythrocyte, the cell's membrane properties change, altering the flow of nutrients and other substances in and out of the cell. Because these pathways are different from those in healthy erythrocytes, the scientists hope to develop drugs that will block the pathways of parasitized cells but have little or no effect on healthy erythrocytes. Alternatively, with a better understanding of pathway differences, the scientists might be able to design a toxic agent that would enter parasitized cells but could not enter healthy erythrocytes.

HEBREW UNIVERSITY OF JERUSALEM



The Hebrew University-Hadassah Medical School tops a small hill on the university's campus at Ein Kerem, a suburb of Jerusalem.

The giant of university scientific research in Israel is the Hebrew University of Jerusalem, with 2,500 research projects currently under way. Starting from the three research institutes that opened with the university in 1925, research at Hebrew University has expanded across the scientific spectrum from microbiology to astrophysics, from solar energy to quantum chemistry.

"The Hebrew University is the major scientific institution in Israel, by whatever standards you measure this," said Amnon Pazy, the former university president, during a recent interview. "The areas in which we are strongest in relation to the world are mathematics, some areas in medicine and biology, theoretical chemistry, solid state physics, astrophysics and, of course, agriculture."

The corner stones for the Hebrew University campus were laid on Mount Scopus in Jerusalem in 1918. Today more than 22,000 students attend the university on campuses at Mount Scopus and two other sites in Jerusalem—Givat Ram and Ein Kerem—and at Rehovot, west of Jerusalem on the coastal plain. The sciences enroll more than 30 percent of all students and half of the Ph.D candidates.

Since the university opened in the 1920s, much of its scientific research has aimed at improving the health of the people and developing the land. The medical faculty contributed greatly to the eradication of malaria and other endemic diseases that plagued settlers. The university now has special units to carry on the research against malaria, leishmaniasis, schistosomiasis and gastroenteric disorders. The Leishmaniasis Unit serves as the World Health Organization's International Reference Center on Leishmaniasis.

Research in the university's agriculture faculty, which opened in 1942, has fueled the growth of the country's agricultural sector. It has developed better varieties of grapes, cotton, oranges and tomatoes, increased the yield of vegetable and grain crops, reduced the damage of pests and soil contamination, and developed more efficient methods of using water. In addition, it has helped boost Israeli flower exports from almost nothing 30 years ago to nearly $200 million annually now.

One of the university's biggest successes has been the development of drip irrigation techniques. Field trials of the techniques near Eilat in the 1960s demonstrated that drip irrigation could be used to grow vegetable crops with saline water under desert conditions. The use of drip irrigation has since spread around the globe, and millions of acres of farm land are now being irrigated by this method.

Hebrew University has also conducted important research in molecular biology. For example, university scientists used this approach to deal with tomato yellow leaf curl virus, which is spread by the tobacco whitefly and damages tomato crops. With USAID funding support, the investigators characterized the viral DNA. They developed a simple diagnostic test that can provide the information needed to stop or slow the spread of the disease. The European Economic Community subsequently commissioned the researchers to conduct a worldwide survey of this viral disease.

The Israel-United States Cooperative Development Research Program (CDR) has funded about a dozen research projects involving Hebrew University. CDR has been particularly supportive of Hebrew University's biomedical research and has approved research projects to investigate malaria, leishmaniasis and other diseases affecting humans and animals. Hebrew University scientists are also involved in CDR projects dealing with water resources, tropical crops, aquaculture, pest control and other development issues.

A CDR project with Cameroon, where malaria is also endemic, is studying the mechanisms of malaria resistance in people with a deficiency of the enzyme glucose 6-phosphate dehydrogenase, or G-6PD. The enzyme is encoded by a gene on the X chromosome and produced by erythrocytes. Persons lacking the G-6PD genes are subject to bouts of severe hemolytic disease (a potentially life-threatening bleeding disorder). Since women have two X chromosomes (men have only one), they will have two, one or none of the G-6PD genes. Women at risk of malaria who have the gene on only one chromosome are fortunate, because they have mixed populations of red blood cells. Apparently the G-6PD-deficient red cells provide resistance against malaria, while nondeficient cells prevent severe G-6PD deficiency (hemolytic disease). Consequently, more women with this mixed genetic trait survive in regions with severe endemic malaria. The CDR scientists are examining several aspects of this malaria-resistance trait to acquire the knowledge that would lead to the identification of immunological mechanisms for possible use in a vaccine and the development of an effective antimalarial treatment.

LEISHMANIASIS

CDR is also funding research into leishmaniasis, a group of diseases in humans and animals around the world caused by a variety of protozoan parasites (*Leishmania*). Transmission of these leishmanial diseases occurs through the bite of certain sand flies. While an effective vaccine against leishmaniasis would be a great benefit, there is also a need for effective new antileishmanial drugs.

A CDR project with Kenya is exploring two promising drugs, glucan and tuftsin, that may be effective against cutaneous leishmaniasis and visceral leishmaniasis (kala-azar). Normally, components of the immune system—scavenger cells called macrophages—will absorb and destroy protozoan parasites. In the case of leishmaniasis, the parasite has evolved a mechanism to avoid destruction after absorption and, in fact, effectively hides within the macrophage, multiplying there to kill the cell, burst out and repeat the cycle. The researchers have found that glucan and tuftsin (derived from sugar and immunoglobulin protein, respectively) activate the macrophages, allowing them to destroy the absorbed parasites. Because these agents do not appear to have severe side effects, their use as immune-system activators may be less dangerous than the toxic drugs now used to treat leishmaniasis.

Investigator Rive Sarfstein sets up an ELISA (enzyme-linked immunosorbant assay) for the specific diagnosis of kala-azar, using the pure antigen dp72. This CDR project with Brazil is developing simple, effective diagnostic tests for the disease.

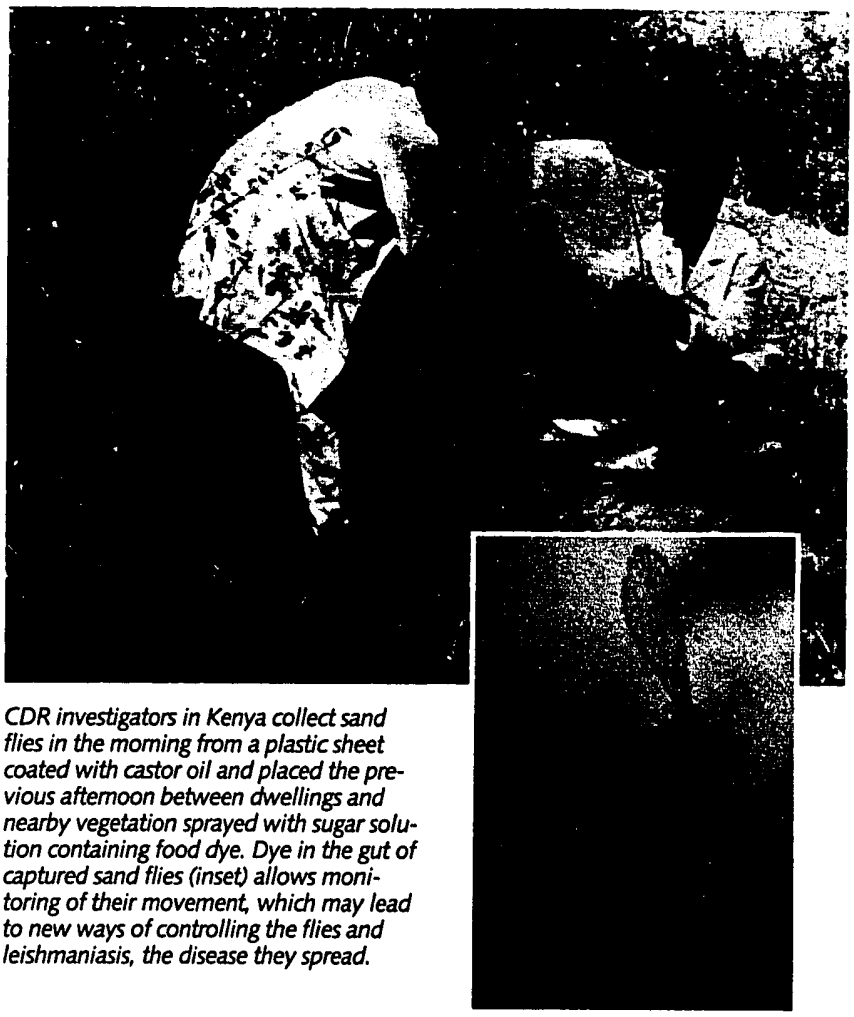
A related CDR project with Brazil is developing simple, effective tests to diagnose kala-azar, monitor the disease and identify carriers of the causative parasite, *Leishmania donovani*. Untreated kala-azar is a chronic, often fatal disease characterized by fever, anemia, progressive wasting and enlargement of the spleen and liver. It is endemic to China, Africa, South America, the Middle East, the Mediterranean basin and the Indian peninsula. Kala-azar may be largely unreported, since it can be hidden by other disease or confused with malaria. It may also be increasingly prevalent because of the disappearance of household spraying programs, aimed against malarial mosquitoes, that may frequently have also killed sand flies that spread leishmaniasis.

In the New World, about 90 percent of American kala-azar is found in Brazil, where it is chiefly a rural, children's disease. But recently a higher incidence has been found among adults and in the suburbs of São Paulo and Rio de Janeiro. Present diagnostic tests involving the sampling of tissue from the liver or spleen can be unreliable, uncomfortable, costly and dangerous. Serodiagnostic tests on crude antigens can also be unreliable, especially in Brazil, where Chagas' disease is coendemic. Blood serum from patients with Chagas' disease, caused by *Trypanosoma cruzi*, frequently crossreacts with antigens from *Leishmania* parasites. The CDR scientists plan to overcome these limitations by developing very specific and sensitive diagnostic tests employing cloned DNA probes that could be used on blood samples. The serodiagnostic tests would use highly purified antigens that are specific to kala-azar and would not crossreact with other diseases. The DNA probes would test for specific DNA sequences in the parasites and could distinguish between *Leishmania* species. These tests could be used for mass screening in endemic areas and thereby help stop the spread of kala-azar.

Scientists in another CDR project with Kenya are approaching the leishmaniasis problems by looking for ways to attack the parasite in its vector, the sand fly.

Typically, sand flies ingest *Leishmania* parasites during blood meals on infected animals (reservoirs) and deposit the parasites when biting humans. Certain fungi and bacteria can kill *Leishmania* in the sandfly gut. Sand flies also feed on plants, and some plant chemicals might kill ingested parasites. The CDR researchers are therefore working to identify plants that might have an adverse effect on sand flies or the *Leishmania* they carry and to clarify the role of sandfly fungal infections (mycoses) in the epidemiology of leishmaniasis.

A CDR project with Portugal has aimed at still another link in the chain of leishmaniasis transmission: dogs. In areas where canine kala-azar occurs, dogs play social and economic roles as pets and work animals. More important, they are a *Leishmania* reservoir and live closely with humans. Since sand flies, the *Leishmania* vector, seldom fly more than 80 to 100 meters, protecting dogs against leishmaniasis may prevent its transmission to humans. The scientists have isolated components of leishmanial strains from infected dogs and humans. The components have been used as specific diagnostic reagents that might be suitable for use in a vaccine. And they have already been incorporated in assays that have improved the ability to diagnose the disease.



CDR investigators in Kenya collect sand flies in the morning from a plastic sheet coated with castor oil and placed the previous afternoon between dwellings and nearby vegetation sprayed with sugar solution containing food dye. Dye in the gut of captured sand flies (inset) allows monitoring of their movement, which may lead to new ways of controlling the flies and leishmaniasis, the disease they spread.

Other Diseases

African trypanosomiasis, another protozoan disease, afflicts about 1 million people across Central Africa at any one time. The disease is caused by *Trypanosoma* species and strains transmitted by tsetse flies. It is commonly called sleeping sickness in humans and nagana in other mammals. As a disease of cattle, nagana creates a tremendous socio-economic impact by inhibiting livestock production in an area of Africa larger than the continental United States (General Development chaper). Trypanosomes have evolved a mechanism to evade the host immune system. With its large variety of antigens, a trypanosome population can present different antigens at various times in the same host or patient. Such variation makes it difficult to develop a simple vaccine against a few specific antigens, since parasites expressing other antigens from the repertoire would survive, reproduce and cause illness. Also, existing drugs are relatively ineffective or highly toxic.

Scientists in a CDR project with Kenya have therefore been investigating new treatment target sites on trypanosomes. In particular, they have been looking at proteins associated with the subsurface array of microtubules, the structural members in trypanosome cells. Characteristics of the microtubules suggest they might play an essential role in the parasite's survival. The microtubule-associated proteins may be specific to trypanosomes but not to mammals. The CDR scientists are seeking to identify such specific proteins that can be used as targets for drugs delivered by protein-specific monoclonal antibodies and for

CDR investigators in Portugal take blood samples and examine dogs in a village where leishmaniasis is endemic. By learning how to control the disease in dogs, researchers may be able to prevent its spread via sand flies to humans.

new drugs based on the specific functional properties of the proteins. Initial work turned up two unique microtubule-associated proteins, which are being studied for possible use in vaccines or treatments. The work has been of special scientific interest because it demonstrated that antibodies can penetrate the cell of the trypanosome and kill the cell from within, a possibility that had been dismissed previously when blood serum antigens were assumed to act exclusively at the cell surface.

Bancroftian filariasis is another important disease in the tropics. It is caused by the tiny nematode (worm) *Wuchereria bancrofti*, which is transmitted by mosquitoes to humans. The disease is debilitating and affects an estimated 80 million people worldwide. In Kenya, bancroftian filariasis is a serious problem in Coast Province, where a CDR project has begun. The scientists are developing diagnostic tools, based on highly specific monoclonal antibodies, that are more accurate, sensitive and convenient to use than existing tests. The new diagnostic tools will be used to survey the distribution of filariasis in the study area and to monitor infection in patients before and after treatment.

In Ghana, a CDR project has generated knowledge that may lead to a better, less dangerous vaccine for whooping cough, still a major disease among children in developing countries that causes several million deaths each year. The whole-cell vaccine introduced in 1945 has been very successful in controlling whooping cough. But the vaccine occasionally produces severe side effects, including convulsions with about one of every 1,750 doses and severe permanent neurological damage with an estimated one of every 310,000 doses. The CDR researchers found strong evidence that the enzyme adenylate cyclase, produced by the bacterium *Bordetella pertussis*, plays a role in the development of whooping cough and triggers a strong immune system response against the disease. This information suggests that the enzyme can be used instead of the whole *B. pertussis* cell to make a safer whooping cough vaccine. It might also be used in a more effective diagnostic test.

Another CDR project, with Guatemala, uncovered new knowledge about the mechanisms of dysentery, a disease prevalent in developing countries. The CDR scientists investigated a toxin produced by the bacterium *Shigella dysenteriae* 1, that they suspected plays a key role in dysentery. In particular, *Shigella* toxin appears to stimulate mast cells, present in the intestinal lining, to release substances that lead to diarrhea. The study results showed substances from the mast cells do contribute significantly to diarrhea; therefore, prevention of those secretions could be a new way of treating this disease.

General Development

"We need to promote the steady expansion of growth in the developing world. ... Our aid policies must do more to address population pressures; to support environmentally responsible, sustainable development; to promote more accountable government and to foster a fair distribution of the fruits of growth among an increasingly restive world population."

— Bill Clinton,
U.S. president

The Israeli scientific community has developed expertise in a broad variety of fields ranging from earth sciences to human behavior in addition to such commonly recognized areas of excellence as irrigation and desert agriculture. Developing-country scientists are tapping this expertise in many areas—with funding and encouragement from the U.S.-Israel Cooperative Development Research Program (CDR)—to help solve specific development problems in their home countries.

CDR, for example, is investigating a number of important development problems facing animal husbandry. Trypanosomiasis, which plagues human populations across Central Africa, also severely limits cattle production in nearly half of the 15 million square kilometers of Africa that are suited for livestock production. Of breeds demonstrating some tolerance to trypanosomiasis, the West African Longhorn, or N'Dama, shows the most. A CDR project with Gambia and U.S. collaborators is searching the N'Dama DNA for the gene or genes that confer tolerance. The scientists plan to use a relatively new class of genetic marker—restriction fragment length polymorphisms (RFLPs)—to identify and map the gene. This information will help breeders introduce the gene into other cattle breeds as well as introduce other desirable genetic characteristics into the N'Dama without losing trypanotolerance.

Graduate student Anne Shalom (inset) sets up a DNA sequencing gel as the first step in a search for genetic markers of the microsatellite type for use in a CDR project with Gambia to map trypanotolerance in cattle. DNA sequencing gels show a series of microsatellites, which appear as short tracts of regularly alternating columns of bands interspersed in the irregular banding patterns of the surrounding DNA sequence.

Researchers repair a seismographic station in Costa Rica during a CDR project with six Central American countries to develop ways to collect and assess data more efficiently and use the data more effectively.

Earth Sciences

Another development problem involves the collection of river and stream flow data needed for the design and construction of highways, railroads, bridges, water supply systems and flood protection projects. Without such data, money is wasted through the overdesign of some structures and the loss, due to underdesign, of others. Because of the relatively high cost and difficulties in maintaining networks of gauging stations, adequate stream-flow data are often lacking for the ephemeral streams that come and go seasonally in arid regions of developing countries.

In Botswana, CDR scientists are using magnetized tracing particles and other methods to evaluate the stream regime and flow attributes of ephemeral streams. Knowledge gained by injecting a dose of magnetized particles and tracing their movement downstream over two or three years will help the scientists estimate the aggregate stream flow with less cost and difficulty than by using traditional gauging methods. Traditional gauging stations are more easily washed away by floods, a loss not only of instruments but of valuable data that could greatly improve the planning of infrastructure construction projects. The methods developed by the project should be useful for planning development projects in Botswana and other developing countries, especially those that depend on surface water for domestic, agricultural, industrial and other needs.

Israeli expertise in earth sciences is also underpinning a CDR seismic project with the six Central American countries. Earthquakes have caused millions of dollars in damage and killed thousands recently in developing countries. These hazards must be considered during the design and planning of developments of all types if the damage from future earthquakes is to be minimized. Yet many developing countries do not have the scientific or economic resources to collect high quality seismic data and assess them effectively. The CDR project therefore aims to tailor methods of collecting and assessing data so they will generate maximal understanding with minimal resources. In particular, the CDR scientists are creating the techniques to design optimal seismic monitoring networks and testing them for the conditions that prevail in Central America, where the earthquake potential is high and detailed seismological information is lacking. The scientists are also developing new approaches and computational methods to produce the best hazard assessments from data collected by the monitoring systems.

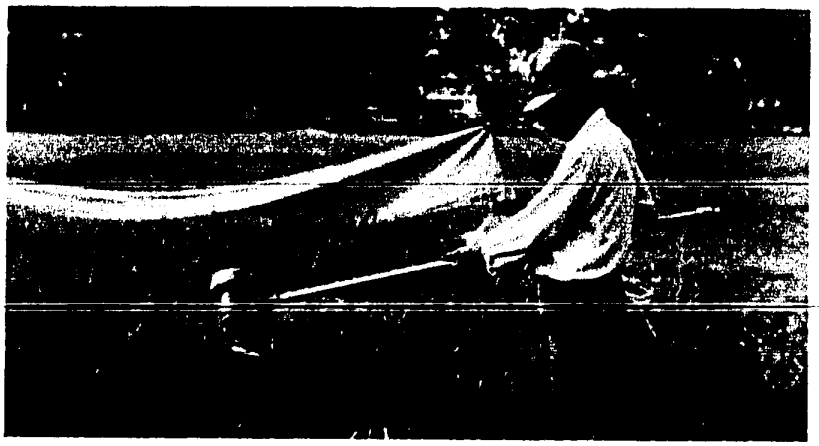
ENGINEERING

CDR funds some engineering research and development projects that produce technologies appropriate to developing countries. One of the most successful of these has been a project with Thailand to develop a compact, reliable, inexpensive cashew nut sheller for use by farmers and small-scale processors. Cashews are a tropical crop grown in many developing countries. Thailand, in particular, has been expanding cashew cultivation to provide another source of rural cash income. The country currently exports 75 percent of the nuts unshelled. Farmers could increase the value of their cashew crops by shelling the nuts themselves. But affordable shellers were primitive and inefficient, and high-production shellers were only affordable to large processing plants. The CDR engineers studied primitive and high-tech shellers and then produced a compact, manually operated sheller that was affordable to farmers. The sheller was immediately popular. The engineers also produced a semiautomatic sheller that could be run with an electric motor. This project was featured in a television feature broadcast in some 70 countries.

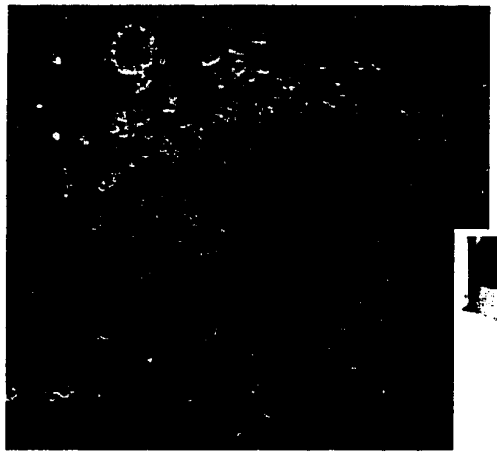
Another CDR project with Thailand is attempting to reduce the volume and increase the effectiveness of pesticides that farmers have traditionally applied to crops via backpack sprayers. Only about 20 percent of the pesticide applied this way lands on the target plants; the other 80 percent is wasted, polluting the environment instead of protecting the crop. Improvements in the accuracy of application would allow reductions in the amount of pesticide used, reducing production costs and environmental pollution.

Conventional sprayers create droplets of widely ranging sizes; tiny droplets drift away in the wind and large ones run off the plants. The new sprayer uses a spinning disc to produce droplets of generally uniform size; the size can by varied by changing the disc speed or flow rate. A battery-powered charger also gives the droplets a small electrostatic charge that spreads the droplets more evenly as they fall and pulls them toward the grounded plant surfaces. Consequently, charged droplets even reach hidden surfaces on the under side of leaves and on lower leaves, sheltered by upper foliage, that would be missed by noncharged droplets. Early field trials indicate that significantly more of the charged spray lands on target than uncharged spray when applied to short plants such as rice and soybeans. Because of the difficulty in spraying tall plants, such as corn, there were no significant differences between spraying methods. The Israelis have gone on independently to improve the batteries used in the sprayer, and negotiations are under way to commercialize the sprayer design.

Another CDR engineering project with Thailand is attempting to improve the productivity of solar ponds, which are a potentially good source of thermal energy in regions where salt, water and sunshine are plentiful. Solar ponds collect solar energy and store it as thermal energy, which can be used to generate electricity. In regular ponds, sunlight heats the bottom, which then heats the bottom water. The heated water expands, becomes less dense and rises,



A Thai farmer tests a low-cost electrostatic low-volume sprayer, developed through a CDR project. The new sprayer deposited up to five times more insecticide on the rice than did a conventional sprayer. In another test on a soybean field, the new sprayer was 3.9 times more effective than conventional ones.



A Thai technician (below) filters N-acetyl sulfapyridine for a treatment being tested in a project to develop a male antifertility drug. In related work, rat sperm (left) approach an egg surrounded by a mass of follicular cells.

while the surface water loses its heat to the cooler air, becomes more dense and sinks. Solar ponds, however, have thick brine at the bottom and thin salt water at the top; the extreme gradient, or difference, between these salt concentrations inhibits circulation due to heating alone. Even though the bottom brine expands with heat, it is still too heavy with salt to rise through the cooler, denser water above. For this reason, the bottom water of a solar pond can reach temperatures of 40 to 70 C above ambient temperature. The pond's thermal storage capability can provide continuous heat supply despite intermittent sunshine.

In the tropics, though, wind, monsoon rains and daily temperature fluctuations can disturb the salt gradient of the pond. CDR engineers are studying these disturbances, looking for ways to reduce them. The engineers are developing a rugged in situ electronic hydrometer to instantly measure water density at various levels in the pond. Some salt gradients are more resistant than others to wind and other external disturbances. So the engineers are investigating a method to inject brine at certain levels in the pond to create salt gradients that will best resist external disturbances. With these improvements in solar pond operations, the technology can be extended into some regions where weather conditions have previously prevented its use.

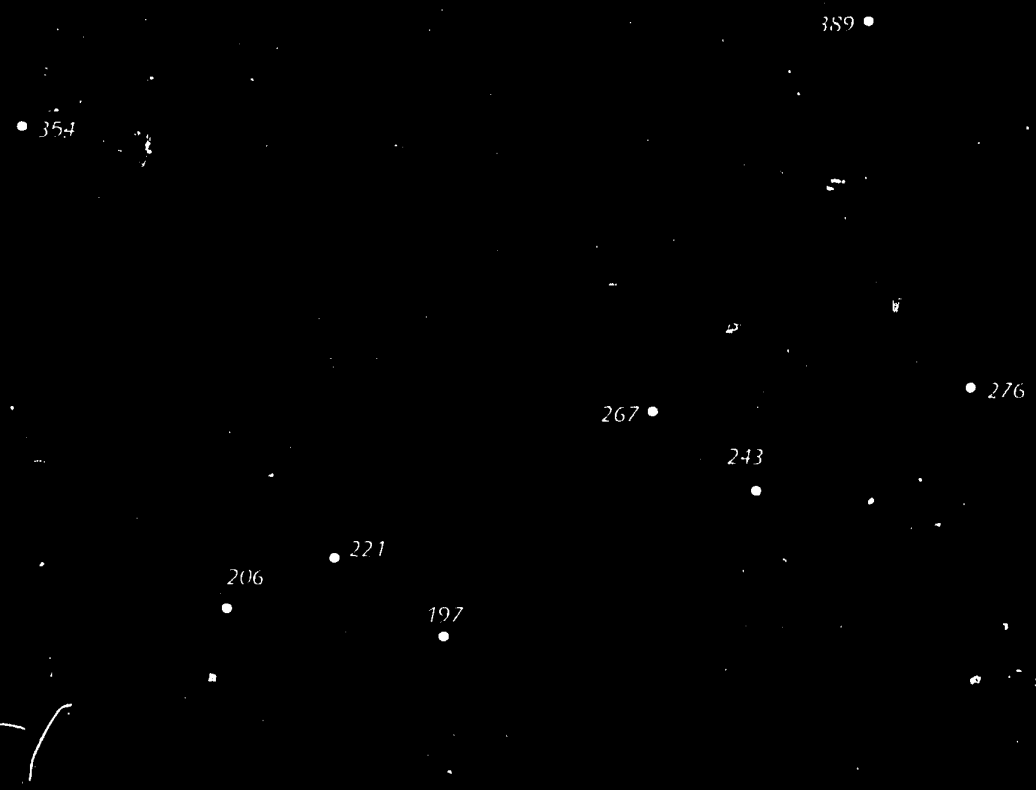
HUMAN BEHAVIOR

Unwanted pregnancies and the resulting overpopulation are serious obstacles to overall progress in many developing countries. In one approach to this behavioral issue, a Thai CDR project is working on a male antifertility drug. The idea came from the observation that some men temporarily lost fertility while taking sulfasalazine, an antibiotic often used to treat ulcerative colitis. The CDR scientists investigated eight sulfa drugs as well as 13 other compounds that they synthesized. The investigators found antifertility activity in 13 agents and identified their basic requisite structures, results that confirmed the project's hypothesis. The potency of the agents, however, was not high. The investigators are now searching for more potent compounds that could be used in the development of a male antifertility agent. Also, because of the similarity in chemical behavior between rat and human male reproductive hormone systems, the antifertility agent may be modified to help control rice-field rats, which are a serious problem in Thailand.

One of the most devastating human behavior problems in developing countries is traffic accidents. Motor vehicle accidents are the primary cause of death between ages 5 and 44. Among infants up to 12 months old, only infectious diseases take a higher toll. In terms of direct costs such as medical expenses and indirect costs such as lost earning power, traffic accidents in developing countries consume an estimated 1 percent of gross national product. In Costa Rica, where a CDR project is studying the problem, the economic losses to motor vehicle crashes are comparable in magnitude to one-third of the annual growth in gross domestic product, which is around 3 percent. In developing countries, little money is available for cars to police traffic. In any case, it has been difficult to ticket and enforce traffic rules where car owners are ipso facto from an economic elite.

CDR investigators, however, are using a unique traffic monitoring system to police traffic, one that is inexpensive and incorruptible. The study will find out which intervention methods are most effective in reducing two of the highest-risk driving behaviors: speeding and tailgating. The monitoring system collects data from a simple device that records speeds and car intervals and from a low-cost video camera that records license numbers. The information is fed into a computerized registry and is being used to identify a pool of high-risk drivers. One group of those drivers will be targeted with a series of intervention measures–warnings, increased insurance premiums, legal measures–designed to decrease speeding and tailgating. Another group of errant drivers not getting interventions will be followed for comparison. Interventions that succeed among these high-risk drivers can be employed with the monitoring system to reduce traffic accidents in Costa Rica and other developing countries.

CDR Preliminary Proposals (Preproposals) Submitted to AID/R



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History of CDR

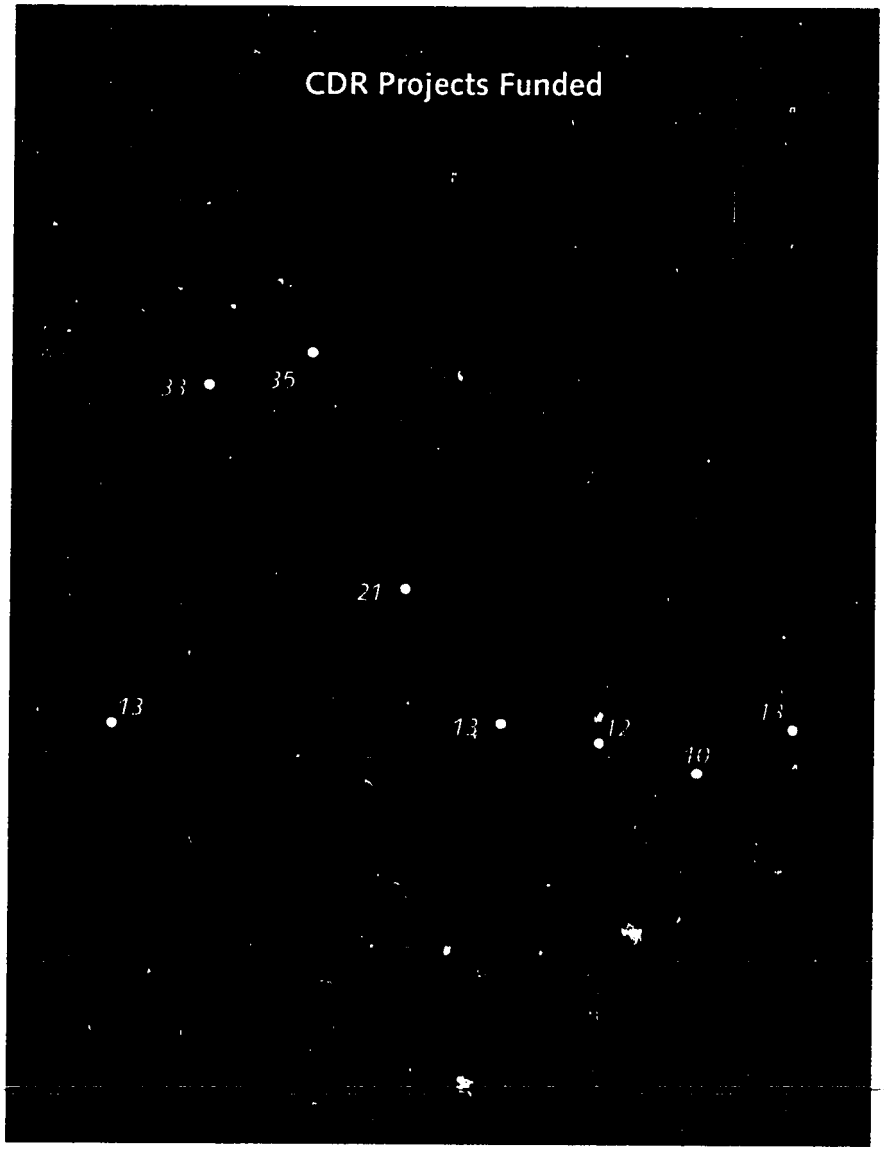
"We have a national interest in securing for others the same rights and values we cherish ourselves and in helping to create a better future for all."

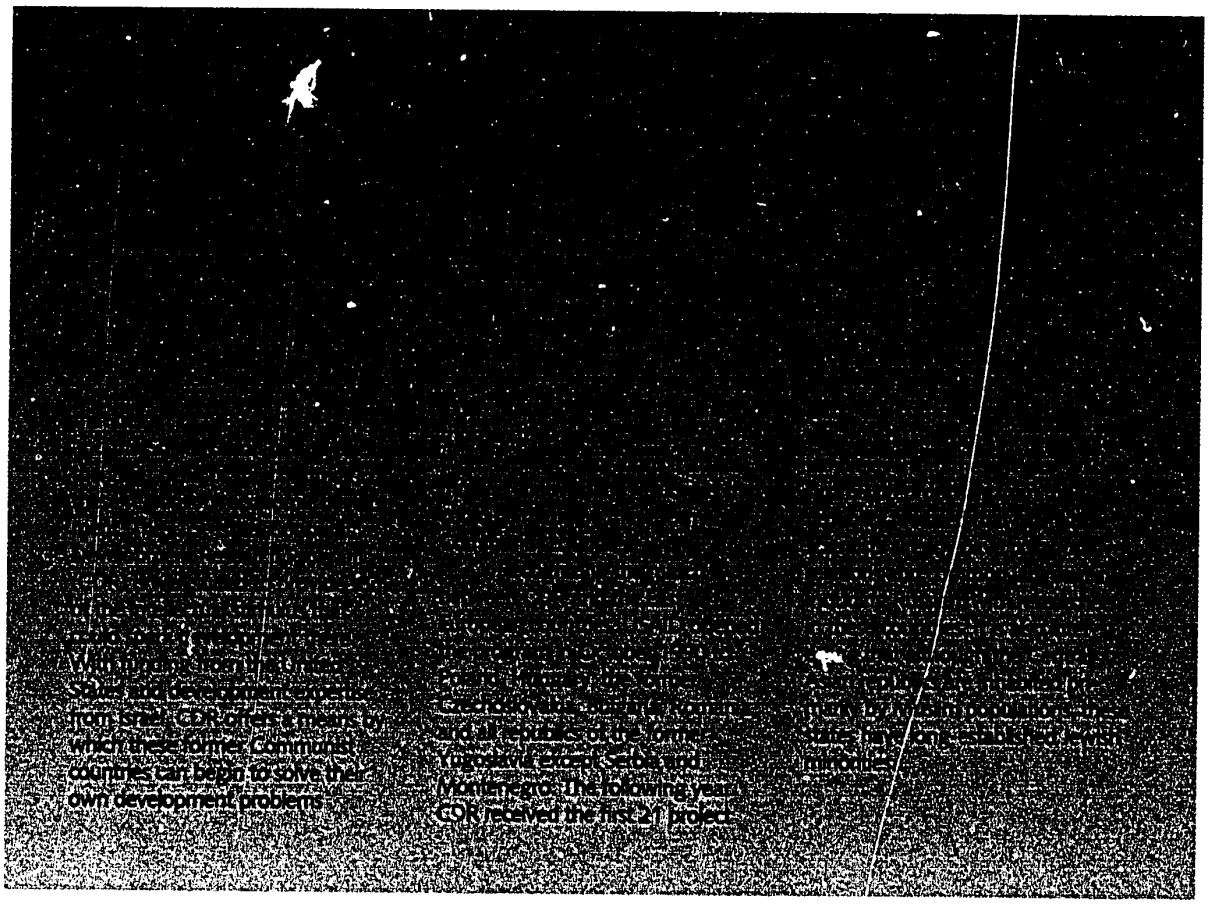
— *Patrick Leahy,*
U.S. senator

The U.S.-Israel Cooperative Development Research Program (CDR) was born in Congress out of a belief that Israel, in the course of its rapid socio-economic development, has mobilized effective scientific approaches to its development problems, approaches which could be of great help to developing countries. But because Israel was not in an economic position to finance broad scientific cooperation with other countries, congressional members thought it appropriate for the United States to partially subsidize the effort.

In October 1984, Congress enacted CDR, and responsibility for it was given to the USAID Office of Research (AID/R, then called the Office of the Science Advisor). This office had been chartered in 1980 to operate a similar scientific development program for U.S. scientific collaboration, the Program in Science and Technology Cooperation (PSTC).

Congress gave CDR $2 million in 1985 and $5 million each of the next three years. In 1989 a new U.S.-Israel effort, the Cooperative

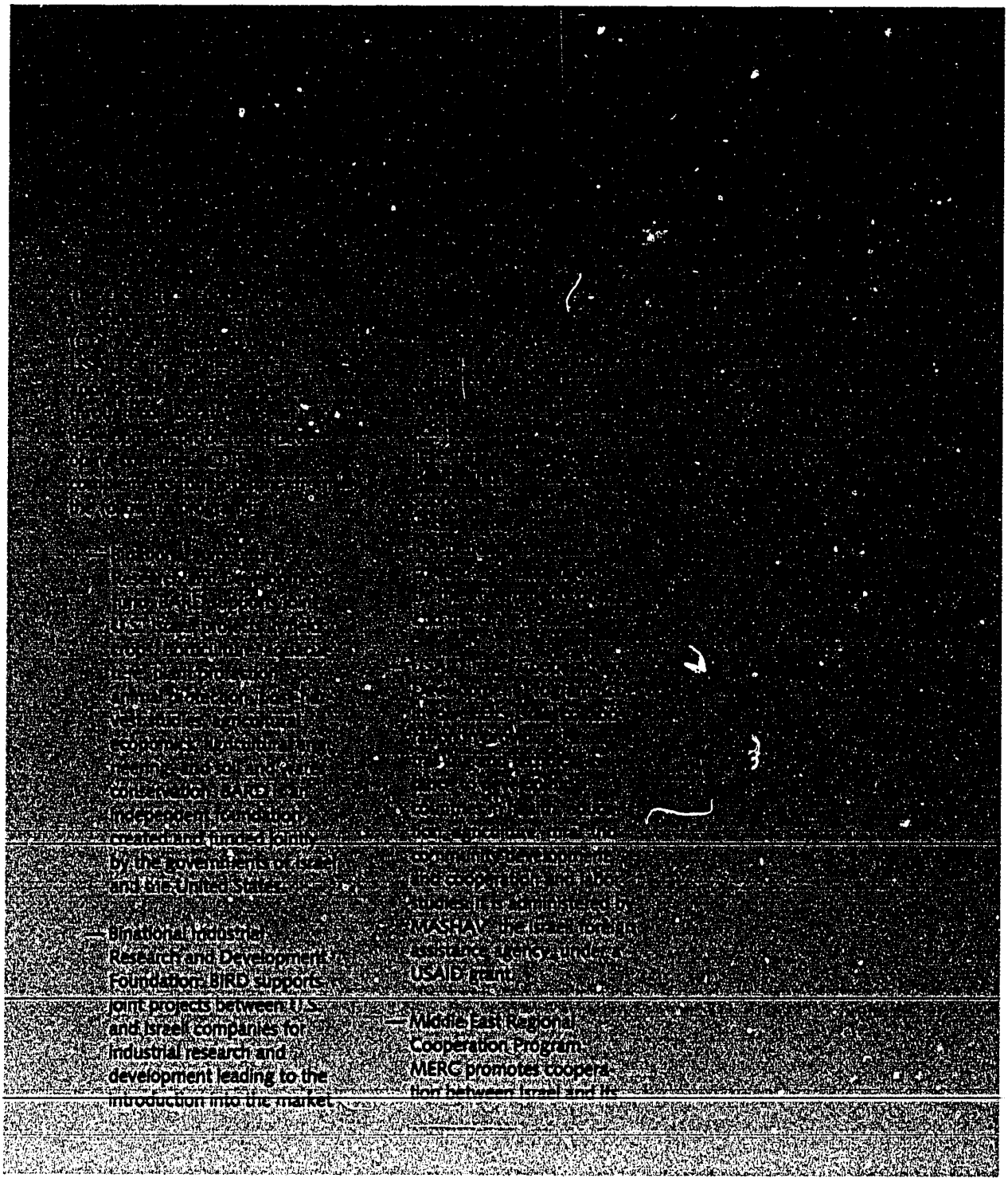




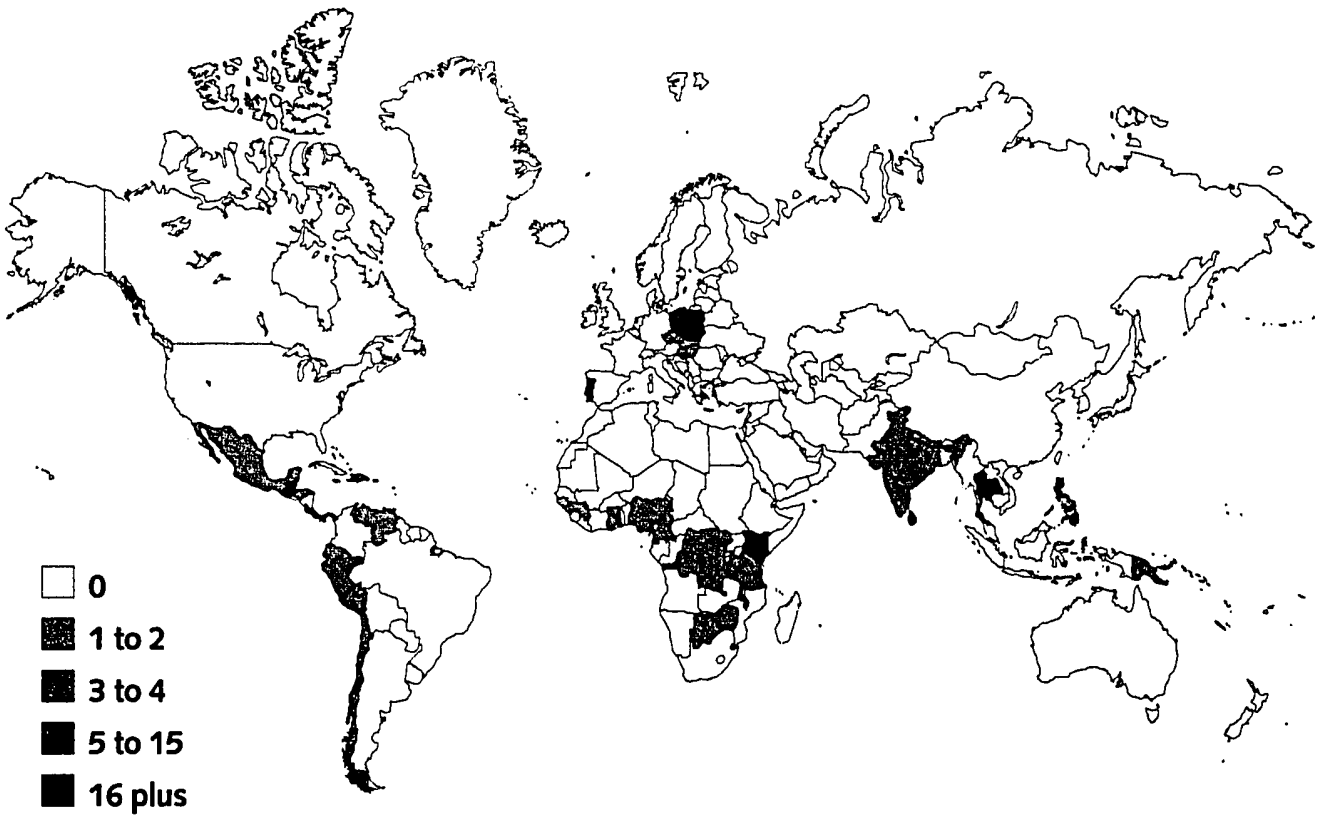
Development Program (see sidebar), was created. CDR was correspondingly reduced to $4 million that year and to $2.5 million in 1990 through 1992. The program was modified in 1991 to include cooperation with East European countries (Poland, Hungary, Czechoslovakia, Bulgaria, Romania and the former Yugoslav republics except Serbia and Montenegro) and in 1993 to include the Baltic states (Lithuania, Latvia, Estonia) and agricultural research in several republics of the former Soviet Union (Georgia, Kazakhstan, Kyrgyzstan, Turkmenistan, Uzbekistan).

CDR has been popular with Israeli and Third World scientists from the beginning. During the first funding cycle, 354 preliminary proposals (preproposals) were submitted to the Office of Research. Since 1985 more than 2,100 preproposals have arrived at the Office of Research. So many have arrived, in fact, that it did not solicit preproposals in 1986 and 1990. In those years, the Research Office simply funded projects that had already won approval in previous years but were stalled owing to lack of funds.

The Office of Research has funded 150 CDR projects since 1985, averaging 20 per year. Initially the maximum grant was $150,000, following the pattern of the PSTC program. However, this level did not seem to suffice, since matching funds are scarcer in Israel than in the United States, where PSTC is based. The CDR limit was raised to $250,000 on a trial basis in 1988 and reduced the following year to $200,000, where it remains.


— Binational Industrial Research and Development Foundation: BIRD supports joint projects between U.S. and Israeli companies for industrial research and development leading to the introduction into the market.
— Middle East Regional Cooperation Program MERC promotes cooperation between Israel and its

Total Number of CDR Projects by Country



CDR Procedures

"Developing countries must build up their own basis for research. Only they will be able to establish the diagnosis and implement the cure."

— *Gro Harlem Brundtland, chair of the World Commission on Environment and Development*

The U.S.-Israel Cooperative Development Research Program (CDR) supports innovative scientific research partnerships between Israel and developing countries. The research ideas are generated by scientists in Israel or a collaborating country, and this requirement is one of the great strengths of the program. The USAID Office of Research (AID/R), which administers CDR, does not propose research projects and look for scientists to perform them. Rather, it invites scientists to submit their own research ideas and funds the best of those that would benefit from Israel's world-class expertise and leadership in applying science to development problems.

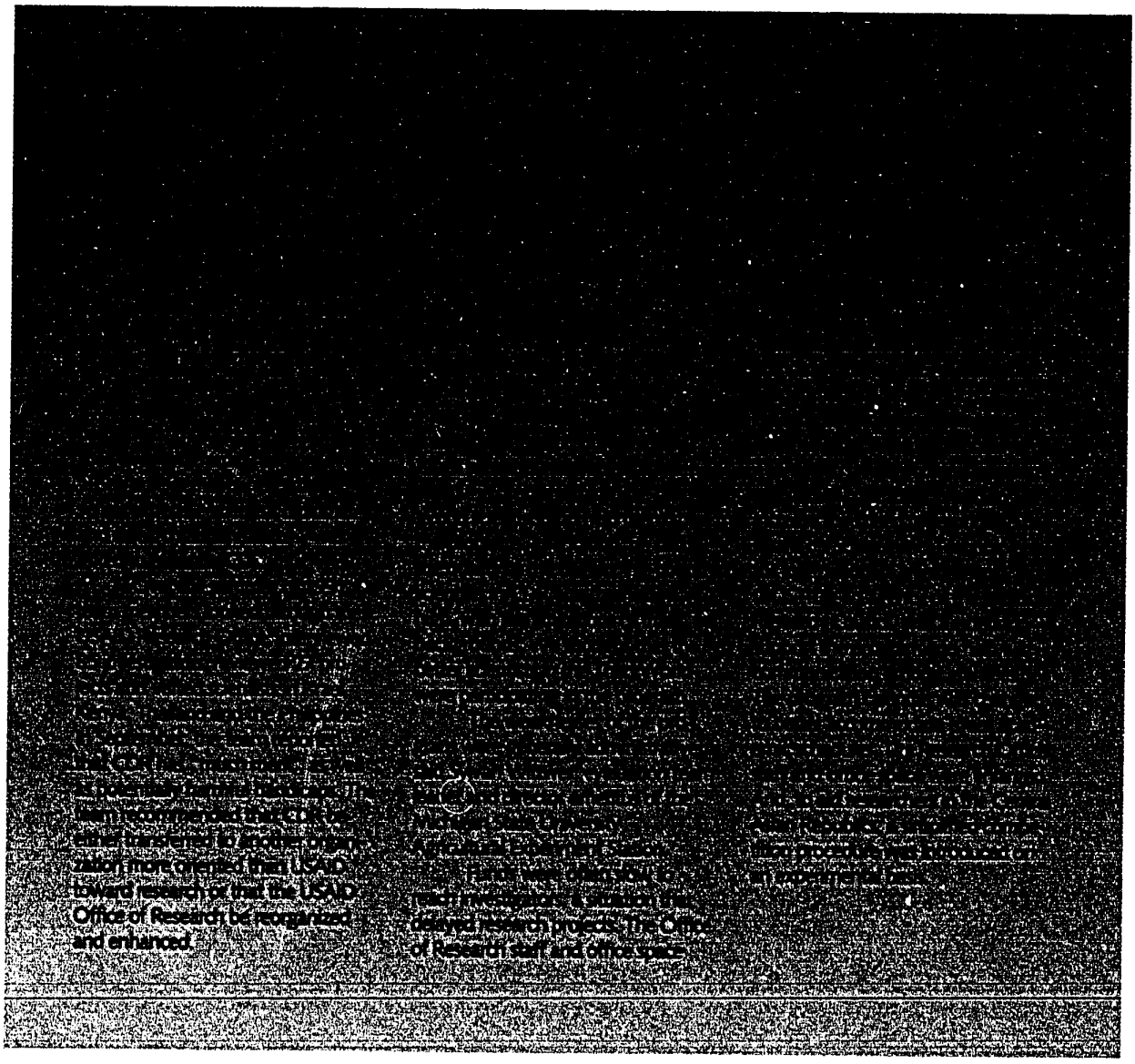
The Research Office evaluates research ideas in a two-step review process, basing its judgment on four broad criteria: innovation, scientific merit, relevance to development and ability to improve research capacity in developing countries.[1] Innovation implies cutting-edge research, the testing of new hypotheses and development of new technologies. Scientific merit includes the soundness of the proposed project as well as the scientific importance of the knowledge and understanding to be gained. The proposal must also address a development problem, such as a tropical disease or desertification, that is an issue beyond the borders of the country where the project is done. The research project must also be designed so that it strengthens the capacity of the host country scientists to investigate other development problems in the future. Finally, the research project must provide for meaningful intellectual collaboration. Although Israel is the source of scientific expertise for this program, CDR is not simply a vehicle for transferring technology and new information. It is a scientific partnership.

Research proposals that meet CDR's four general criteria must also match Israeli expertise. This includes certainly the areas of water resource management, tropical crop development, aquaculture, pest control and human disease reduction but can expand into any area of Israeli leadership, from technology for cutting gem stones to computerized traffic monitoring.

The program usually finances three to five years of the initial research that tests innovative hypotheses. The grants are not renewable. Innovative research often disproves the initial hypothesis on which it was based. But successes that demonstrate new approaches to serious problems more than justify the total program costs; they provide new avenues to the solution of previously intractable development problems. If the hypothesis proves valid, scientists are expected to seek funding from other sources for follow-on research. CDR does not finance the continuation of other USAID projects. Nor does it fund other scientific activities such as surveys, baseline data collection, policy or planning studies or international conferences.

CDR grants range up to $200,000 and may be used for equipment, salaries, training, travel and consultants, so long as all the money is used directly for reaching a specific research goal.

[1] Criteria for the Central Asian program have been modified, as suggested by an external expert panel, to quality of the collaboration, scientific merit, relevance to development and capacity building.



PROJECT SELECTION

Scientists may submit research ideas to CDR anytime via their local USAID mission. But the selection process essentially begins in early summer, when the Research Office formally invites submissions and issues the current guidelines for them. This initial submission is a preliminary proposal, or preproposal, of two to three pages outlining the project and addressing the criteria required by the program. Preproposals need to reach the Office of Research by a specified deadline—Nov. 15 for the most recent cycle—to be considered for the current funding cycle.

Local USAID missions may screen the research ideas before forwarding them to the Research Office, which conducts a

comprehensive screening in Washington. This internal review ensures that the proposed research would be useful to USAID and relevant to development. If a preliminary proposal meets these tests, the Research Office sends the review comments to the scientist along with an invitation to submit a detailed full proposal by Aug. 15.

In October, the Research Office assembles panels of experts in 10 to 20 fields to review full proposals. They evaluate each proposal, recommend whether to fund the proposal and give it a priority score. Afterward, the Research Office ranks all the proposals by score and decides how many of the approved proposals can be financed with the available funds. Each year more proposals are approved than can be funded. Proposals that are approved and not funded in one funding cycle may be held over and funded in a later cycle.

When an approved project is selected for funding, a grant is negotiated with the principal investigator. Negotiations include the investigator's response to weaknesses or issues raised by proposal reviewers. If the investigator responds satisfactorily to the research and administrative questions raised during the negotiations, then the project is funded. Failure to respond satisfactorily usually lowers a project priority score below the funding cut-off level.

PROJECT MONITORING

CDR projects are almost always funded through the Israeli institution and thus are usually monitored by the U.S. science attaché in Tel Aviv, who serves as project officer for all grants to Israeli institutions. Once the project is funded, the CDR project officer becomes the main point of contact between the principal investigator and USAID. Also, the Office of Research frequently arranges for a technical backstop officer from Washington to help with technical questions that may arise.

The CDR project officer keeps abreast of the project through semiannual progress reports from the investigator. The officer may visit research sites to review the findings and ascertain their potential use or may ask the Research Office to arrange site visits by an expert. Project officers are thus in excellent position to gauge the potential for integrating research results into ongoing USAID programs.

In addition, officers at the National Research Council's Board on Science and Technology for International Development (BOSTID) monitor each CDR grant from inception to completion. By following the progress of the projects, BOSTID officers ensure that technical help is provided to projects that need it. Frequently BOSTID arranges for U.S. scientist volunteers to review reports or visit grantees to help with the projects.

BOSTID staff also arrange occasional networking meetings for CDR grantees and ensure that they are invited to other appropriate networking meetings for Research Office grantees. The staff provide an electronic mail service, EINSTEIN, and can help researchers in Israel and developing countries find suitable collaborators.

CDR evaluates completed projects in a number of areas for different reasons. For example, several projects in the research areas of biomass and human health have been evaluated to assess the overall progress of Research Office efforts in these fields. And when a former CDR investigator asks for funding of a new project, the peer review panel examines the results of the first project to judge the scientist's productivity.

CDR Projects Funded in 1988-1992, by Research Area

(For projects funded in 1985-1987, see earlier booklet)

KEY:
HOST COUNTRY. Grantee Institution; PRINCIPAL INVESTIGATOR. Grant year. Title. Description. CDR file number

AQUACULTURE

ECUADOR. Hebrew U. Jerusalem; COHEN, D. 1990. Induction of Gonad Maturation in *Penaeus vannamei*. Regulate gonad maturation in *P. vannamei* females toward achieving continuous and unlimited shrimp fry production. Extract and purify gonad stimulating factors from continuously fecund *Macrobrachium rosenbergii* and apply them to *P. vannamei*. C9-147

HAITI. MIGAL-Galilee Technological Center; MARCHAIM, U. 1989. An Integrated Macroalgae Cultivation Farm on Sand. Develop a macroalgae cultivation farm where seaweed is grown on arid land using saline water. Develop a spray culturing technology. C8-104

PHILIPPINES. Agricultural Research Org., Israel; SCHROEDER, G. 1989. The Role of Sulfate Ions in the Potential to Replace Refined Feeds With Agricultural Residues in Mariculture. Evaluate the role of sulfate ions and their reduced reaction products, sulfides, in governing the availability of natural foods in saline-water earthen ponds used for fish and shrimp farming. C7-042

PHILIPPINES. Israel Oceanographic & Limnological Research; LUBZENS, E. 1989. Mass Culture of the Rotifer *Brachionus plicatilis*—Isolation of Clones and High-Yield Production. Set up high-yield mass cultures of rotifers for use as food in raising marine fish larvae, to promote fingerling production. C7-099

PORTUGAL. Ben-Gurion U. Negev; MARKUS, A. 1989. Microencapsulation of Fish Feed. Develop new microencapsulated fish feeds that will be palatable and nutritious to fish, be stable to chemical and bacterial decomposition, float in the fish ponds, and contain appropriate vitamins and growth stimulants. C7-138

THAILAND. Ben-Gurion U. Negev; COHEN, Z. 1988. Production of Eicosapentaenoic Acid (EPA) by Microalgae. Screen fast-growing algal species that contain high concentrations of EPA and determine the optimal environmental and nutritional conditions for EPA production. C8-136

THAILAND. Israel Oceanographic & Limnological Research; BEN-AMOTZ, A. 1989. Production of Beta-Carotene and Other Carotenoids by the Alga *Dunaliella* and Their Use as a Source of Vitamin A. Use the unique capability of the halotolerant alga *Dunaliella* to synthesize large amounts of beta-carotene for production of beta-carotene and other valuable carotenoids. C8-011

A Waurhani in Ecuador holds a plantlet distributed through a CDR project to identify, select, and domesticate useful indigenous plants. The project aims to boost the economy of food gatherers and help them preserve their way of life.

ARID LAND AGRICULTURE

BOTSWANA. Ben-Gurion U. Negev; KAGAN-ZUR, V. 1990. Cultivation of *Terfezia pfeilii*—the Kalahari Truffle. Domesticate the prized Kalahari truffle and develop an indigenous cash crop that requires little water and can be grown on Kalahari soils using simple agricultural techniques. C9-114

KENYA. Agricultural Research Org., Israel; SHAINBERG, I. 1991. Infiltration, Runoff and Erosion in Semiarid Soils From Kenya. Improve water management in the arid and semiarid land of Kenya and other semiarid regions to stabilize and increase crop production and to avoid soil erosion by water. C11-255

KENYA. Ben-Gurion U. Negev; PASTERNAK, D. 1988. Fodder Production With Saline Water. Select salt-tolerant forage crops suitable for irrigation with highly saline water or for production on saline soils. C7-199

PHILIPPINES. Agricultural Research Org., Israel; MINGELGRIN, U. 1990. Water Transport and Storage for Gravity-Powered Irrigation. Develop efficient, inexpensive and easy-to-perform procedures for the treatment and maintenance of water conveyance systems. C5-049

PHILIPPINES. Ben-Gurion U. Negev; LIPS, H. 1992. Salt Resistance of Rice. Study the effects of salinity and salinity-resistance thresholds of key processes of plant physiology and biochemistry. Map the process thresholds to guide improvement of crop varieties and design of simple agrotechniques to enhance production under saline conditions. C12-157

PORTUGAL. Ben-Gurion U. Negev; LIPS, H. 1989. Carob (*Ceratonia siliqua* L.) Productivity as Affected by Inorganic Nitrogen Fertilization. Develop advanced agrotechniques for the more efficient use of irrigation and fertilization to optimize carob productivity. Study the effect of environmental parameters on uptake and assimilation of nitrate and ammonium at different K^+ levels. C8-134

PORTUGAL. Colegio de Postgraduados; FIGUEROA, B. 1989. Adaptation to Salt and Water Stress by Pulses Tolerant to Environmental Stress of the High Altitude Deserts. Developing a double line source sprinkler method that can be used to test new plant varieties for tolerance to salt and water stress. C7-039

SWAZILAND. Agricultural Research Org., Israel; BRESLER, E. 1990. A Methodology for Evaluation of New Irrigation Techniques Considering Application Uniformity. Develop a field technique and statistical analysis procedure to quantify the differences among irrigation methods due to variations in water application uniformity, transpiration and their effects on crop yields where irrigation varies widely. C9-156

BIODIVERSITY

COSTA RICA. Centro Agronómico Tropical de Investigación y Enseñanza; MULLER, L. 1988. In Vitro Germ Plasm Preservation of *Musa* Species. Develop methodologies for in vitro germ plasm preservation of edible banana cultivars and other varieties and species that represent valuable material for genetic improvement. C8-165

ECUADOR. Tel Aviv U.; FRIEDMAN, J. 1989. Application of a Novel Method for Selection and Domestication of Indigenous Plants, Among Food Gatherers, in Ecuador. Document highly popular indigenous plants with edible or medicinal properties in Ecuador. Establish a seed bank and nursery to supply the plants for distribution among potential growers. C8-159

KENYA. Ben-Gurion U. Negev; MENDLINGER, S. 1988. The Germ Plasm Collecting, Evaluation and Breeding of Southern African Edible Cucurbits. Study and evaluate the potential of some semidomesticated and wild cucurbits and amaranths of tropical and subtropical Africa. C8-142

BIOMASS CONVERSION AND FERMENTATION PROCESSES

CZECH REPUBLIC. Czechoslovak Acad. Sciences; NERUD, F. 1992. Conversion of Lignocellulose by White-Rot Fungi. Determine the efficiency of lignin degradation, including the ability of white-rot fungi to attack softwood, hardwood, grass and synthetic lignin. Evaluate the use of selected mutants to treat wastewater and environmental pollution. C12-047

GHANA. Hebrew U. Jerusalem; CHET, I. 1991. Upgrading of Lignocellulose Waste With White-Rot Fungi for Ruminant Animal Feed. Maximize the use of rice straw by producing mushrooms and using the spent compost for animal feed. Rice straw is the main substrate for straw mushroom (*Volvariella*) cultivation in the tropics. C9-184

GUATEMALA. Inst. Centroamericano de Investigación y Technología Industrial; PORRES, C. 1989. Biological Upgrading of Pretreated Coffee Pulp. Reduce antiphysiological substances in coffee pulp by chemical and physical pretreatments and bioconversion to obtain a product that can be incorporated in larger amounts than those found in current ruminant feeding rations. C8-108

GUATEMALA. Tel Aviv U.; ROLZ, C. 1988. Degradation of Plant Cell Walls by "Cellusomes" of Anaerobic Bacteria. Understand the interaction between resting cell suspensions of cellulolytic bacteria and cell walls of plant cells in suspension culture. C8-027

MEXICO. Ben-Gurion U. Negev; GOTTLIEB, M. 1988. Development of Novel Products From Guayule Rubber. Develop new products by modifying guayule polyisoprene by selective copolymerization with silicone derivatives to yield materials of superior chemical, thermal and mechanical properties. Guayule is a plant adapted to arid lands. C8-123

PHILIPPINES. Agricultural Research Org., Israel; KRIKUN, J. 1988. Endomycorrhizal Fungus Inoculum Production Techniques. Develop methodology to increase vesicular-arbuscular mycorrhiza inoculum in quantities that can be used for large-scale experimental or commercial purposes. C5-082

POLAND. MIGAL-Galilee Technological Center; DOSORETZ, C. 1992. Degradation of Recalcitrant Toxicants of *Phanerocheaete chrysosporium* Immobilized on Granular Adsorbents. Develop and characterize a stable bioreactor system for the physical adsorption/biological mineralization of recalcitrant xenobiotics at high organic loadings, based on *P. chrysosporium* fungus. C12-182

ENGINEERING

COSTA RICA. Hebrew U. Jerusalem; Richter, E. 1990. A Traffic Monitoring and Driver Behavior Modification System. Decrease the rate of motor vehicle crashes in Costa Rica by developing methods for the epidemiologic study of high-risk driving behaviors and ways to avoid them. C8-043

CZECH REPUBLIC. Hebrew U. Jerusalem; BALEK, V. 1992. Soils and Clays Contaminated by Organic Hazardous Pollutants. Design technology for treating hazardous organic waste-containing clays and soil; determine conditions for lowering the transport rate of organic pollutants. C12-219

CZECH REPUBLIC. Hebrew U. Jerusalem; HAAS, Y. 1992. Studies of Atmospheric Chemistry and Air Pollution. Study ozone-olefin reactions and their significance to atmospheric chemistry; develop research and monitoring capabilities in Czech Republic to augment pollution control strategies. C12-223

GUATEMALA. Petroleum Infrastructure Corp.; RABINOWITZ, N. 1991. Development of Methodology and Procedures for Monitoring Seismic Data in Central America. Upgrade seismological capabilities in Central America by introducing and developing new concepts and methodologies in seismicity monitoring and earthquake hazard assessment. C11-229

NIGERIA. U. Delaware; CHENG, A. 1991. A Low-Cost Microcomputer Program for Modeling Multiaquifer Systems. Build a microcomputer-based regional groundwater modeling system for use by water resources planners in countries where large-scale computer facilities are scarce and the availability and quality of field data are limited. C9-200

POLAND. Israel Inst. Tech.; NARKIS, M. 1992. Electrically Conductive Structured Polymer Blends. Advance science and technology of structured polymer blends, conductive plastics and conductive polymer blends by developing model compounds of electrically conductive incompatible polymer blends that have unique electric/dielectric properties. C12-097

SLOVAKIA. Hebrew U. Jerusalem; SCHICK, A. 1992. The Response of Fluvial Systems to Large-Scale Land-Use Changes. Improve the understanding of the response of fluvial systems to an abrupt, temporally well-defined change in land use, using geomorphic documentation of such a response resulting from farm collectivization in Slovakia. C12-090

TANZANIA. U. Dar es Salaam; MAJAJA, B. 1991. Developing Mechanical Harvesting and Handling Systems for Sisal. Study the physical properties of sisal and evaluate parameters important for the optimal design of cutting devices for a mechanical harvest system. Evaluate methods to collect and cut leaves. C11-027

THAILAND. Asian Inst. Tech.; GUPTA, C. 1988. Farmer-Driven Electrostatic Low-Volume Sprayer. Develop a farmer-driven, electrostatic, low-volume sprayer for small-scale farmers. C8-205

THAILAND. Asian Inst. Tech.; GUPTA, C. 1990. Engine-Driven Potato Digger With Oscillating Blade for Small Farmers. Develop an oscillating-perforated-disk, share-type digger with a foam-rubber-coated rotary sieve for harvesting potatoes to reduce draft requirement, minimize tuber damage, lower the cost of potatoes and reduce the amount of labor required. C9-098

THAILAND. Khon Kaen U.; LIMYINGCHAROEN, S. 1988. Monitoring and Controlling the Salt Gradient in the Solar Pond. Develop a simple procedure for solar pond operation for tropical developing countries. Develop an electronic hydrometer and identify major factors affecting the top interfacing boundary of the salt gradient in solar ponds. C8-200

HUMAN HEALTH

BRAZIL. Weizmann Inst. Sci.; JAFFE, C. 1989. Kala-Azar in Brazil: Immunological and Genotypic Characterization of Viscerotropic *Leishmania*. Develop diagnostic tests for visceral leishmaniasis and identify and characterize potential reservoirs for the transmission of *Leishmania donovani chagasi*. C7-103

CAMEROON. Hebrew U. Jerusalem; GOLENSER, J. 1988. Protective Mechanisms Against Malaria Associated With Glucose 6-Phosphate Dehydrogenase (G-6PD) Deficiency. Explore the specific biochemical-biological mechanisms by which the otherwise deleterious deficiency of G-6PD in local human populations has given its carriers a degree of resistance to the malarial parasite *Plasmodium falciparum*. C7-163

COSTA RICA. Tel Aviv U.; OVADIA, M. 1991. Isolation, Characterization and Neutralization of Hemorrhagic Toxins From the Venom of the Snake *Bothrops asper*. Study the dangerous venom hemorrhagins of *B. asper*, a pit viper, to improve the clinical antivenin produced in Costa Rica. C11-004

KENYA. Hebrew U. Jerusalem; GALUN, R. 1990. The Induction of Resistance to Lice by Immunization. Develop a vaccine against lice through the isolation and characterization of antigenic material from the louse gut. C8-164

KENYA. Hebrew U. Jerusalem; KEYNAN, A. 1990. Increasing the Persistence of Bacillar Mosquito Larvicides: a Biological Approach. Further the biological control of mosquitoes by producing an improved mosquito larvicide based on the highly specific mosquito larval toxins of *Bacillus thuringiensis israeliensis* and *B. sphaericus*. C9-175

KENYA. Kenya Medical Research Inst.; KOECH, D. 1990. Bancroftian Filariasis: Development of Immunodiagnostic and Seroepidemiologic Methods and Use in Filariasis Surveys. Develop monoclonal antibodies reactive with circulating antigens of *Wuchereria bancrofti* and develop a simple immunoassay for diagnosis of *W. bancrofti* infection in humans. C9-173

KENYA. Weizmann Inst. Sci.; GOLDMAN, R. 1988. Glucan and Tuftsin—Potential Antileishmanial Agents. Evaluate the potential of tuftsin and glucan as antileishmanial agents. C7-061

PAPUA NEW GUINEA. Ben-Gurion U. Negev; POLLACK, Y. 1988. Diagnosis of Drug-Resistant *Plasmodium falciparum* by DNA Probes. Develop specific DNA probes enabling the diagnosis of chloroquine- and pyrimethamine-resistant *P. falciparum* in blood samples. C8-126

PERU. U. Peruana Cayetano Heredia; MIRANDA, E. 1989. The Epidemiology and Biology of *Cryptosporidium* Infection in Peru and Israel. Determine in two different locations the epidemiology of *Cryptosporidium* infection, examine strain differences and develop in vivo and in vitro techniques to permit amplification of the parasite. C8-099

THAILAND. Chiang Mai U.; MAKONKAWKEYOON, S. 1988. In Vitro Immunotherapeutic Effect of Interleukin 1 and Interleukin 2 on Monocytes and Lymphocytes of Leprosy. Elucidate the abnormality in cell-mediated immunity in human leprosy by studying the quantity and functional intactness of T lymphocytes producing IL-2 and monocytes producing IL-1 by examining the function of T helper and T suppressor cells. C8-196

THAILAND. Mahidol U.; THARAVANIJ, S. 1988. DNA Probe for the Diagnosis of Vivax Malaria. Apply DNA probe of *Plasmodium vivax* for the diagnosis of vivax malaria. C8-114

PLANT PATHOLOGY AND PEST CONTROL

COSTA RICA. Agricultural Research Org., Israel; BEN-YEHOSHUA, S. 1992. Extending Life of Mango and Melon by Modified Atmosphere Packaging. Extend the life of mangoes and melons by using modified atmosphere packaging; combine this technique with curing at high temperatures and humidities to reduce decay and toxic residues of fruits. C11-076

DOMINICAN REPUBLIC. Agricultural Research Org., Israel; CHALUTZ, E. 1990. Biological Control of Postharvest Diseases of Fruits. Develop biological control mechanisms for two major citrus postharvest diseases by the use of natural microbial antagonists. C8-087

DOMINICAN REPUBLIC. Agricultural Research Org., Israel; RACCAH, B. 1988. Characterization and Control of Cucurbit Viruses. Develop reliable techniques to reduce severe losses caused by cucurbit viruses. C8-077

HUNGARY. Agricultural Research Org., Israel; LURIE, S. 1992. Prevention of Pathogen Infection and Insect Infestation by a Postharvest Heat Treatment. Develop a single nonchemical method to prevent insect and fungal infestation of harvested fruit, slow fruit ripening and extend postharvest shelf life. C12-081

KENYA. Ben-Gurion U. Negev; MARGALIT, J. 1988. Development of *Bacillus* Species to Protect Grain From Harvest Time Till Reaching the Consumer. Screen for potent *Bacillus* pathogens among natural infestation habitats within silos to develop novel formulations of commercial bacterial pathogens. C8-048

MAURITIUS. FRM Agricultural Sci. Partnership; HOFSTEIN, R. 1988. Screening of New *B. thuringiensis* Strains for Integrated Pest Management in Mauritius. Develop new biological pesticides against important lepidopteran pests of major crops. C8-100

NEPAL. Tel Aviv U.; GUTNICK, D. 1991. Specific Inhibitors of Pectolytic Enzymes for Control of Postharvest Diseases. Screen strains of *Streptomyces* for ability to produce inhibitors of polygalacturonase of *Botrytis cinerea* by concentrating on polyphosphates. Study the effectiveness of inhibitors to control soft rot induced by *B. cinerea*. C9-039

PERU. Tel Aviv U.; WAHL, I. 1991. Utilization of *Hordeum spontaneum* Resistance for Barley Leaf Rust Control. Incorporate various types and levels of resistance to barley leaf rust disease, derived from rich reservoirs present in the wild barley *H. spontaneum* C. Koch, into Peruvian barley cultivars susceptible to leaf rust disease. C7-114

PHILIPPINES. Agricultural Research Org., Israel; NAVARRO, S. 1990. Application of Modified Atmospheres Under Plastic Covers for Prevention of Losses in Stored Grain. Study the applicability of sealed plastic liners for the preservation of stacked sacks of grain in warehouses and in the open and develop techniques for the application of modified atmospheres and fumigations in stacked sacks of grain stored under plastic liners. C7-053

PHILIPPINES. Hebrew U. Jerusalem; CHET, I. 1992. Crop Residue Decomposition With *Trichoderma* for Disease Management in Rice-Based Cropping Systems. Investigate the biology and ecology of *Trichoderma* in rice and rice-based cropping systems along with the application of *Trichoderma* for straw decomposition and disease management in upland and rainfed rice-based cropping systems. C12-040

POLAND. Agricultural Research Org., Israel; ZILKAH, S. 1991. In Vitro

Biological Indexing in Fruit Tree Quarantine System. Develop a fruit quarantine system based on tissue culture procedures for the induction, maintenance and micropropagation of plant tissues grafted with imported plant material and for indexing plants. C11-065

POLAND. Weizmann Inst. Sci.; GRESSEL, J. 1992. Reducing Herbicide Inputs to Reduce Costs and Prevent and Overcome Resistance. Ascertain whether biorationally designed mixtures delay or prevent herbicide resistance; simultaneously reduce herbicide input to decrease environmental impact and prevent resistance. C12-217

SRI LANKA. Agricultural Research Org., Israel; PRUSKY, D. 1988. Prevention of Postharvest Disease by Modulation of Natural Antifungal Compound Concentration in Ripening Avocados. Study the modulation of a natural antifungal compound as a possible tool to prevent postharvest diseases in avocado. C8-089

THAILAND. Agricultural Research Org., Israel; SHAAYA, E. 1989. The Use of Natural Products for the Control of Stored-Product Insects. Search for oils with insecticidal or repellent capabilities that may be used to prevent insect damage in stored grain and pulses. C5-077

THAILAND. Chulalongkorn U.; WONGSIRI, S. 1989. Biological Control of the Varroa Bee Mite (*Varroa jacobsoni*). Find a way to utilize Asian bee workers to control varroa mite infestations of European bee colonies. C9-045

THAILAND. Khon Kaen U.; PIMSAMARN, S. 1988. Use of Labiatae Plant Extracts for Insect Control. Explore the possibility of using phytochemical substances from common Labiatae weeds for insect control. C8-198

VETERINARY SCIENCES

GAMBIA. Hebrew U. Jerusalem; SOLLER, M. 1990. Mapping Genes for Trypanotolerance in N'Dama Cattle of West Africa. Mapping the trypanotolerance loci of the West African trypanotolerant N'Dama cattle with respect to the trypanosensitive Zebu and locating specific genetic markers in close linkage to the trypanotolerance loci. C9-018

KENYA. Kimron Inst.; LIPKIND, M. 1991. Antigenic and Functional Properties of Hemagglutinin-Neuraminidase Glycoprotein of Avian Paramyxoviruses. Study the topological arrangement between the functionally active sites and the antigenic epitopes for avian paramyxoviruses and the relationship this has with viral virulence. C8-026

POLAND. Hebrew U. Jerusalem; PINCHASOV, Y. 1992. The Control of Chicken Growth for Optimal Egg Production in Broiler Breeders. Control pullet growth by an ad libitum self-restricting diet containing an anorectic agent. Determine the effect of the pullet prelay growth on subsequent egg production in hens. C12-224

PORTUGAL. Hebrew U. Jerusalem; BECKER, Y. 1988. Development of Molecular Techniques for Foot and Mouth Disease Virus (FMDV) Diagnosis. Apply molecular technologies to the diagnosis of FMDV. C7-152

SWAZILAND. Agricultural Research Org., Israel; ASHBELL, G. 1988. Dual Purpose Sorghum as Source for Food and Feed for the Semiarid Tropics. Introduce and advance a farm-scale production of sorghum for food and good quality livestock feed in developing countries of the semiarid tropics. C8-092

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(Number is CDR file number. Country names refer to countries of non-Israeli principal investigators or collaborators.)

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GROUNDWATER (developing microcomputer program to model regional groundwater systems in developing countries), C9-200. Morocco, Nigeria, Tanzania, United States; p. 4.

GROUNDWATER, CONTAMINATION (investigating soils to filter hazardous organic materials from groundwater), C12-219. Czech Republic; p. 5.

IRRIGATION (developing methodology to evaluate new irrigation techniques), C9-156. Swaziland; pp. 2-3.

IRRIGATION IN SAND (assessing potential of desert sand sheets for modern agricultural development), C7-143. Ghana; pp. 2, 16.

IRRIGATION, SALINE-WATER (improving crops grown with saline water by applying fresh water at critical growth stages), C11-131. Philippines; p. 2.

IRRIGATION, SALINE-WATER (improving saline-water irrigation through KNO_3 fertilization), C5-001. Philippines; pp. 1-2.

IRRIGATION, SALINE-WATER (using advanced sand culture methods for growing crops with saline water), C5-325. Peru; pp. 2, 15.

IRRIGATION, WATER TRANSPORT AND STORAGE (stabilizing soil in irrigation ditches and reservoirs), C5-049. Philippines; p. 3.

RAINWATER (developing computer model for hydrology of paddy land), C7-187. Thailand; p. 3.

RAINWATER (devising systems to harvest rainwater in sandy soils for livestock), C5-064. Kenya; p. 4.

RAINWATER (improving soil penetration and reducing erosion in dryland farming), C7-036. Portugal; pp. 3-4.

RAINWATER (studying plant covers to improve water management and reduce erosion), C11-255. Kenya; p. 4.

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FODDER (developing improved salt-tolerant animal fodder), C7-199. Portugal; p. 7.

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WHEAT (developing techniques to screen wheat for highly drought- resistant varieties), C5-038. Portugal; p. 8.

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For Further Information...

A brief information statement that explains how to submit preliminary proposals (preproposals) is available to prospective CDR participants. This brochure is updated annually and may be obtained without charge from

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Acknowledgments

This booklet was written by Hugh McIntosh with much help from Anne Dix and other Research Office staff and was designed by Gerry Gagne. We would like to thank the many people inside and outside USAID who contributed their time and expertise to this project.

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