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VERTEBRATE DAMAGE CONTROL RESEARCH IN AGRICULTURE

ANNUAL REPORT 1977

Denver Wildlife Research Center
U.S. Fish and Wildlife Service

U.S. Agency for International Development

1977 ANNUAL PROGRESS REPORT*

COOPERATING AGENCIES:

U.S. Fish and Wildlife Service

U.S. Agency for International Development

Agricultural Agencies in Africa, Asia, and Latin America

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This research was conducted with funds provided to the U.S. Fish and Wildlife Service by the Agency for International Development under PASA's "Control of Vertebrate Pests: Rats and Noxious Birds," ID/TAB-473-1-67, and "Control of Vampire Bats," ID/TAB-000-10-76.

THE COVER

The photographs on the cover (from left to right, top to bottom) illustrate the scope of research involved in the AID-sponsored International Programs of the Denver Wildlife Research Center.

The common vampire bat has caused economic loss and hardship for livestock producers of Latin America. The transmission of paralytic rabies and possibly other diseases, blood loss, myiasis, and reduced production contribute to a multimillion dollar problem.

Systemic treatment of cattle by intraruminal injection of the anticoagulant diphenadione is one of two highly effective, safe, and economical means of vampire bat control developed by DWRC researchers.

Rodents cause severe losses of coconuts in almost all countries where they are grown. A control method developed by DWRC biologists has yielded dramatic results in field tests in Latin America and the Philippines.

Quantification of the magnitude of food losses to vertebrate pests on a worldwide basis is meager at best. Many of the published discussions of food losses inevitably focus on microorganisms or arthropods and make only passing mention of vertebrate pests. The development of reliable survey methods for vertebrate damage problems will result in a greater appreciation of the role of vertebrate pests in food losses.

Backup research at DWRC by specialists in such fields as toxicology, animal behavior, physiology, bioelectronics, and chemistry play a major role in the development of effective control methodology.

Vertebrate damage in agriculture involves a variety of crops and species of animals, primarily birds and rodents. Direct losses occur typically at planting and sprouting, during the milk or dough stages (for grains), just before harvest, or under postharvest storage conditions. Some damage may be mechanical, as when crops are trampled or dislodged by animals digging for insects or other food. Losses may alter the food value, as when rats selectively remove the germ from stored corn, or may result from the contamination of foods with urine, feces, feathers, or hair.

In many areas of the world, rodent damage to field crops causes severe reduction of the human food supply, and increases the risks of small-farm agriculture. In localized areas, rodents may be a principal factor limiting crop production; more often, rodents unobtrusively remove a share of production before harvest--crop after crop, season after season. Although there are more than 6,000 kinds of rodents, only about 50 can be considered significant agricultural pests.

A central difficulty in the development of vertebrate damage control technology in many countries has been a tendency to ascribe minor importance to species and environmental differences, and to attempt translation of work from the laboratory to field areas where different species, crops, and environmental factors are involved. Hence, on-site field testing is prerequisite to a successful program. In addition, such an approach affords excellent opportunities for training of local specialists who will ultimately bear the responsibility for vertebrate damage control programs in their countries.

Losses to birds are less well documented than those to rodents. Various species of parrots, parakeets, blackbirds, weavers, doves, seedeaters, pheasants, and waterfowl are among the types of birds known to cause damage in agriculture around the world. Data on crop losses are difficult to assess because damage is usually concentrated in limited areas and, due to the mobility of birds, is often seasonal, sporadic, and difficult to predict.

Research at the DWRC and in the field involves evaluation of different methods including chemical, physical (such as this sublethal electric barrier), biological, and other techniques which have the potential for providing positive benefits in the control of vertebrate damage in agriculture. The species, crop, farming methods, environmental factors, and a host of other considerations may influence the approach to solution of a particular problem.

The Denver Wildlife Research Center is well equipped with modern, scientific instrumentation, providing the capability for laboratory research into all facets of a vertebrate damage problem.

The results of research undertaken by DWRC staff members and cooperators throughout the world are regularly published in scientific and technical journals, progress reports, and special publications, often in the language of the country or countries suffering a particular pest problem. Nearly 200 publications have resulted from the international activities of the DWRC since inception of the program.

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VERTEBRATE DAMAGE CONTROL RESEARCH IN AGRICULTURE

INTRODUCTION

Food--in sufficient quantity for a rapidly increasing world population--is one of the problems facing mankind. In some developing countries, the disparity between population and available food is both widespread and acute, despite the fact that sizable portions of the populations of these countries are engaged in agriculture. Apart from a simple deficit in production, significant amounts of the food and fiber that is produced are lost through destruction or contamination by pests and pathogenic organisms. Vertebrate pests, primarily rodents, vampire bats, and granivorous birds, are responsible for much of this loss.

The U.S. Agency for International Development (AID) has funded a research program at the Denver Wildlife Research Center to develop means of controlling vertebrate depredations to agricultural crops. The overall objective of this project is to increase the available human food supply in developing countries and reduce the risk of severe losses caused by these pests. The ultimate aim of the research program is to develop safe, effective, and economical control methods which are suitable and practical for small farmers and acceptable in the broader context of agricultural development.

Attainment of these goals is approached by (1) in-country programs, (2) outreach activities from the DWRC as requested by AID/Washington or AID Missions, and (3) problem-oriented research activities at the DWRC. Vertebrate damage problems in Africa, Asia, and Latin America are continuously reviewed. Current bird and mammal damage research and development is also reviewed with the aim of adapting new techniques or materials to specific problem situations.

The Section of International Programs of the Denver Wildlife Research Center provides support and direction to field personnel, assists in establishing relevant research objectives for laboratory personnel, and coordinates the team efforts of DWRC and cooperating scientists. General administrative support is provided in the areas of fiscal management, personnel matters, commodity procurement, records management, and coordination of correspondence, reports, and manuscripts. Related activities include representing the program to other organizations, coordinating DWRC-based training for AID participants, briefing visitors, developing cooperative programs with international organizations, providing technical information to USAID Missions or other cooperators, and assisting AID personnel in program development and negotiations with foreign governments.

The Denver Wildlife Research Center is the pioneer animal damage control research institution in the United States and has, for many years, been a recognized leader throughout the world in the development of methods and materials for vertebrate pest control. The large, experienced staff is comprised of specialists in diverse fields, such as field ecology, physiology, pharmacology, wildlife biology, nutrition, statistics, animal psychology and behavior, chemistry, and bioelectronics. Several staff members have foreign service experience and fluency in foreign languages. Denver Center laboratories are exceptionally well equipped with the instrumentation required to conduct research in each of the disciplines involved. Hence, although the staff actually funded under the AID project is quite small, the Section of International Programs may call upon the services and expertise of more than one hundred professional and support personnel from other units of the Denver Center.

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John W. De Grazio	Section Chief
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Michael W. Fall	Biologist
G. Clay Mitchell	Biologist
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Carlos Calvi	Uruguay
Edgar Ortiz	Guatemala
Rogerio Piccinini	Brazil
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[1] Fully funded under the Participating Agency Service Agreement (PASA).

[2] Partially funded under the PASA except as otherwise indicated.

[3] Personnel not funded under the PASA but who participated in research associated with this project.

[4] Foreign nationals assigned to the project and funded by their respective governments except as otherwise indicated.

[5] Foreign nationals who cooperated with the project in major field research or extension activities or who participated in project activities as students or trainees.

[6] Hired under contract for specific assignment.

PROGRAM DEVELOPMENT

During the year, project personnel devoted considerable time and effort to the planning of new or expanded vertebrate damage control research programs. These are briefly discussed here. Detailed information is given in the appropriate Project Papers or other pertinent documents.

Bangladesh

The Bangladesh Agricultural Research Council, of the Government of Bangladesh, requested assistance from the AID Mission in Dacca in assessing the current status of rodent research and control in Bangladesh, and to determine the type of program necessary to address the problem. AID/Dacca, in turn, sought assistance from this project in accomplishing this review and formulating an appropriate response. As a result, the existing AID Agricultural Research Project for Bangladesh was amended to include a vertebrate pest component. The proposal calls for a 5-year program (FY 78 through FY 82) designed to establish an ongoing research capability (as a Vertebrate Pest Division of the Bangladesh Agricultural Research Institute) to adapt and develop vertebrate pest management techniques suited to the needs of small farmers. Included will be technical assistance, participant training, commodities, facility construction, and operational and maintenance support. Technical assistance will be provided by a PASA contract with the Denver Wildlife Research Center.

Philippines

The Philippine Government, recognizing the need for improved pest management systems for the country's farmers, proposed the establishment of a National Crop Protection Center and seven regional centers throughout the Philippines. Basically, the National Crop Protection Center would involve work on all forms of pests, including insects, diseases, nematodes, weeds, mites, and vertebrates. The Rodent Research Center, which was established and is operated in conjunction with the DWRC/AID vertebrate pest control project, will become a project entitled "Control of Vertebrate Pests" within the National Crop Protection Center.

Latin America

The Latin America Bureau, AID/Washington, proposed the establishment of a regional program in Latin America to address the problem of vertebrate pest damage to agriculture, with special emphasis placed on those crops which are predominantly produced by small farmers. To

this end, a Project Identification Paper (PID) and an interim report were prepared. Briefly, the project, as currently envisioned, would consist of two field units--nuclei of outreach activity--to serve the needs of specified regions (e.g. Central America and the Caribbean). If the results achieved under the programs of the first two field units should prove adequately beneficial, a third outreach center could be established for South America at a later date. A Project Paper is currently in preparation.

OUTREACH ACTIVITIES

DWRC staff and consultants traveled extensively in Africa, Asia, Latin America, and Europe. This travel was undertaken in conjunction with ongoing field research activities, at the request of foreign governments through AID Missions or AID/Washington, to participate in international meetings, or to review, evaluate, and coordinate present and future research activities. Such travel involved 439 man-days in the following countries.

Kenya	Bangladesh	Bolivia	Italy
Sudan	Indonesia	Brazil	United Kingdom
Tanzania	Nepal	Colombia	
	Philippines	Ecuador	
		Nicaragua	
		Panama	
		Paraguay	
		Peru	
		Uruguay	

The dates, persons involved, countries visited, and the purpose of each trip are briefly outlined in Table 1. Detailed information is contained in individual trip reports on file at the Denver Wildlife Research Center, Section of International Programs.

Table 1. International travel on technical assistance projects by AID/DWRC personnel or consultants.

Date	Name	Location	Purpose of Visit
Jan 9-21	J. W. De Grazio W. H. Bohl	Tanzania, Sudan, Kenya	Review quelea research project at Arusha; discuss cooperative vertebrate pest control research in Sudan
Jan 26-Feb 27	R. F. Reidinger, Jr.	Bangladesh	Assess vertebrate pest problems in agriculture
Jan 27-Feb 9	G. C. Mitchell R. W. Bullard D. J. Elias	Colombia	Participate in vampire bat control seminar and workshop sponsored by Instituto Colombiano Agropecuario
Mar 13-Apr 4	J. W. De Grazio C. M. Loveless	Philippines	Assist in field evaluation of methiocarb for *Lonchura*; review RRC graduate program
Mar 13-30	C. E. Knittle	Uruguay	Evaluate methiocarb to reduce eared dove damage to sorghum and soybeans
Mar 20-Apr 27	M. W. Fall	U.K., Nepal, Indonesia, Philippines	Visit PICL, U.K., to discuss rodent research; field study of rodent damage to wheat, Nepal; discuss progress of CARE/USAID project, Indonesia; assist in field studies and training, Philippines

May 5-27	G. C. Mitchell	Bolivia	Follow up on vampire bat study being conducted by a Bolivian veterinarian in the Department of Chuquisaca and get information on bird and rodent problems in southern Bolivia
May 16-Jun 8	C. E. Shuart	Brazil, Paraguay, Ecuador, Panama	Discuss ongoing control programs and assist Paraguayan Government in outlining a vampire bat control program
Jun 24-Jul 2	G. C. Mitchell D. D. Badger	Nicaragua	Preliminary work on establishment of socio-economic evaluation study of vampire bat control
Jul-Aug	R. F. Reidinger, Jr.	Bangladesh	Assist GOB in outlining vertebrate pest research project
Sep 28-Oct 7	G. C. Mitchell	Peru, Nicaragua	Discuss vertebrate pest problems, review proposed Latin American Regional Programs
Oct 3-13	R. D. Curnow	Nicaragua, Uruguay	Review project work with bat problems in Nicaragua; review monk parakeet and dove problems in Uruguay
Oct 3-19	J. W. De Grazio	Uruguay, Paraguay	Discuss status of bird, rodent, and bat problems with USAID and Ministry of Agriculture officials
Oct 3-29	J. F. Besser W. H. Bohl	Sudan	Conduct field trials to test methiocarb for repelling quelea from sorghum fields

Nov 19-Dec 14	M. W. Fall	Philippines	Review cooperative research projects in progress at NCPC; attend BIOTROP conference
Dec 1-21	P. J. Savarie	Philippines	Assist in establishing rodenticide testing program; attend BIOTROP conference
Dec 5-9	W. H. Bohl	Italy	Attend IXth Coordinating Committee Meeting in Rome of FAO UNDD/SF Regional Project Research into the control of grain-eating birds (*Quelea quelea*)

FIELD PROGRAMS

Two overseas field programs, involving resident U.S. technicians, are currently maintained under this project. One is located at the Plant Protection Department in Khartoum, Sudan. This project was established on May 12, 1977, by USAID/DWRC in cooperation with the government of the Democratic Republic of the Sudan, Ministry of Agriculture, Food, and Natural Resources. Mr. Wayne H. Bohl, DWRC biologist, entered on duty at this station on May 15, 1977, having been transferred from Arusha, Tanzania. The AID/DWRC vertebrate pest research program for quelea was originally established at the Tropical Pesticides Research Institute (TPRI) in Arusha, but unforeseen difficulties necessitated the transfer of the project to the Sudan. Mr. Bohl is working with 10 Sudanese counterparts.

The second overseas field program is located at the Rodent Research Center (RRC) on the campus of the University of the Philippines at Los Baños (UPLB). The RRC was established in June 1968 as a joint undertaking of the government of the Republic of the Philippines (GOP), U.S. Agency for International Development (USAID), and the Denver Wildlife Research Center (DWRC). In November 1976, the RRC was incorporated as a unit of the Philippine National Crop Protection Center (NCPC). This organization, along with seven affiliated regional centers (RCPC's) has primary responsibility for the research, development, and dissemination of integrated crop protection systems for the country. The NCPC is using facilities of the RRC as its temporary quarters. It has a total scientific and supporting staff of over one hundred individuals, and received its first operational budget from the Department of Agriculture in November.

USAID has cooperated with the Philippine government in developing the RRC, and will continue to provide support for the NCPC and the RCPC's during their initial years of operation. In the area of vertebrate pests, Dr. Russell F. Reidinger, Jr., representing the DWRC, seven Filipino biologists, a number of graduate students, and cooperating personnel work at the NCPC under a project entitled "Control of Vertebrate Pests."

The objectives of the project's field programs, and the activities undertaken during the year toward achievement of these objectives, are summarized in the following reports.

Project personnel collected quelea for food habits studies from a nesting colony of about 1.5 million birds on an area of about 20 hectares in Kassala Province, Sudan.

SUDAN

The red-billed weaver or quelea (Quelea quelea), found in some 25 African countries, is a serious pest species in cereal grain crops, such as sorghum, wheat, millet, and rice. In addition to quelea, there are other bird and rodent damage problems in Africa that are of significant economic importance. The agreement establishing this field program is scheduled to extend through 1981, first as a one-man station with emphasis on quelea depredation research. Later, plans call for the addition of a second biologist and expansion of the program to include research into other vertebrate pest problems, including rodents.

Prior to the establishment of the Sudan project, DWRC biologists conducted quelea damage surveys and carried out related experiments in several African countries between 1971 and 1976. A comprehensive review of these activities was presented in the 1976 Annual Report. These preliminary efforts indicated that chemical repellents, disturbants, and frightening agents offer a promising strategy for reducing crop damage. Hence, the primary objective of this project is to develop direct crop protection methodology rather than concentrating only on population suppression.

Quelea in the Sudan

Quelea biology, migratory patterns, and breeding habits in East Africa have been summarized in previous annual reports. The habits of the subspecies found in Sudan (Q. q. aethiopica) are much the same. Table 2 summarizes the major quelea activity patterns in Sudan relative to roosting, nesting, and occurrence of crop damage in sorghum, wheat, and millet. Figure 1 illustrates the general distribution of quelea and other important grain-eating birds in the Sudan.

Table 2. Major periods of roosting, nesting, and crop damage by quelea in the Sudan.

Area	Period of rainfall	Large concentrations of roosting	Nesting	Cereal crop damage
Northern Sudan	Jun-Sep	Mar-Apr	Sep/Oct	Sep/Nov (dry farms) Feb/Mar (irrigated farms)
Southern Sudan	Mar/Oct	undetermined	undetermined	Oct/Nov

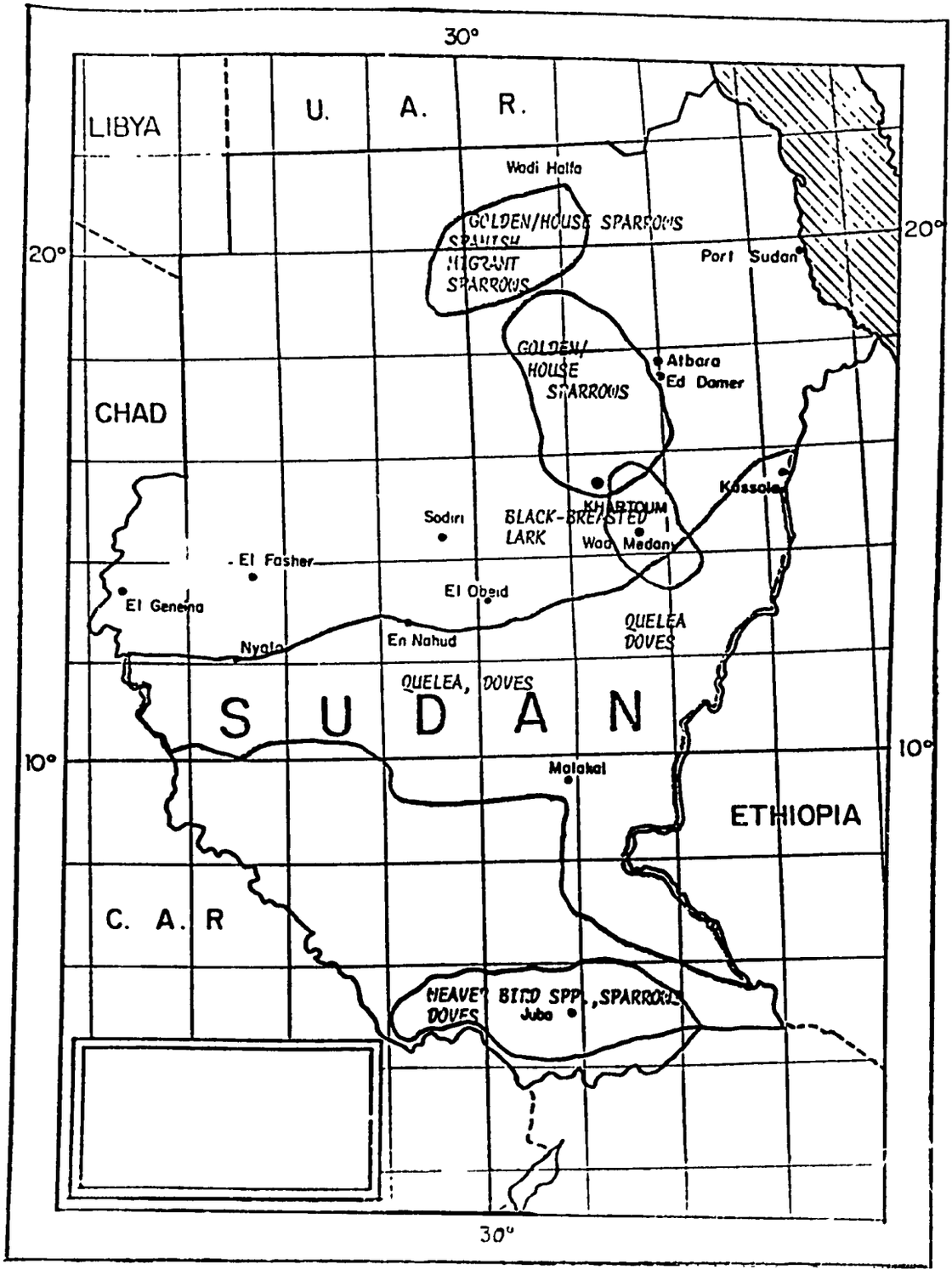


Fig. 1. Distribution of grain-eating birds in the Sudan.

The quelea in Sudan can be classified as locally migratory and able to travel hundreds of kilometers to favorable feeding areas. Banding in African countries has shown that migrations can amount to 1,500 km. Quelea from Ethiopia can be expected to enter eastern Sudan where sorghum production has increased to several million feddans (1 feddan = 0.415 ha) over the past several years. These fields have replaced the grasslands used extensively by quelea in the past.

Figure 2 outlines the sorghum-growing areas and major quelea habitat of Sudan, including breeding and roosting sites that overlap almost all of the grain-growing area. Ninety percent of the grain production in Sudan occurs between latitudes 8° and 15° N. and longitudes 23° and 37° E. This large grain-producing region forms ideal breeding grounds for quelea because of the availability of forests and tall grasses surrounding the cereal fields. Heavy clay soils, coupled with high annual rainfall (400-800 mm) and the absence of all-weather roads or aircraft landing strips, make it difficult to conduct ground surveys of breeding colonies and subsequent control operations efficiently.

Large-scale efforts to control quelea began in the Sudan in 1946. Despite control measures used and the destruction of millions of quelea at roosts and nesting colonies for the past 30 years, the quelea population is currently maintaining itself at a very high and viable level. Table 3 summarizes the control efforts of the Sudanese Plant Protection Department for the years 1970-1978. Many authorities currently believe it would be more advantageous to reduce indiscriminate destruction of quelea throughout each country and concentrate control efforts at nests or roosts in close proximity to croplands.

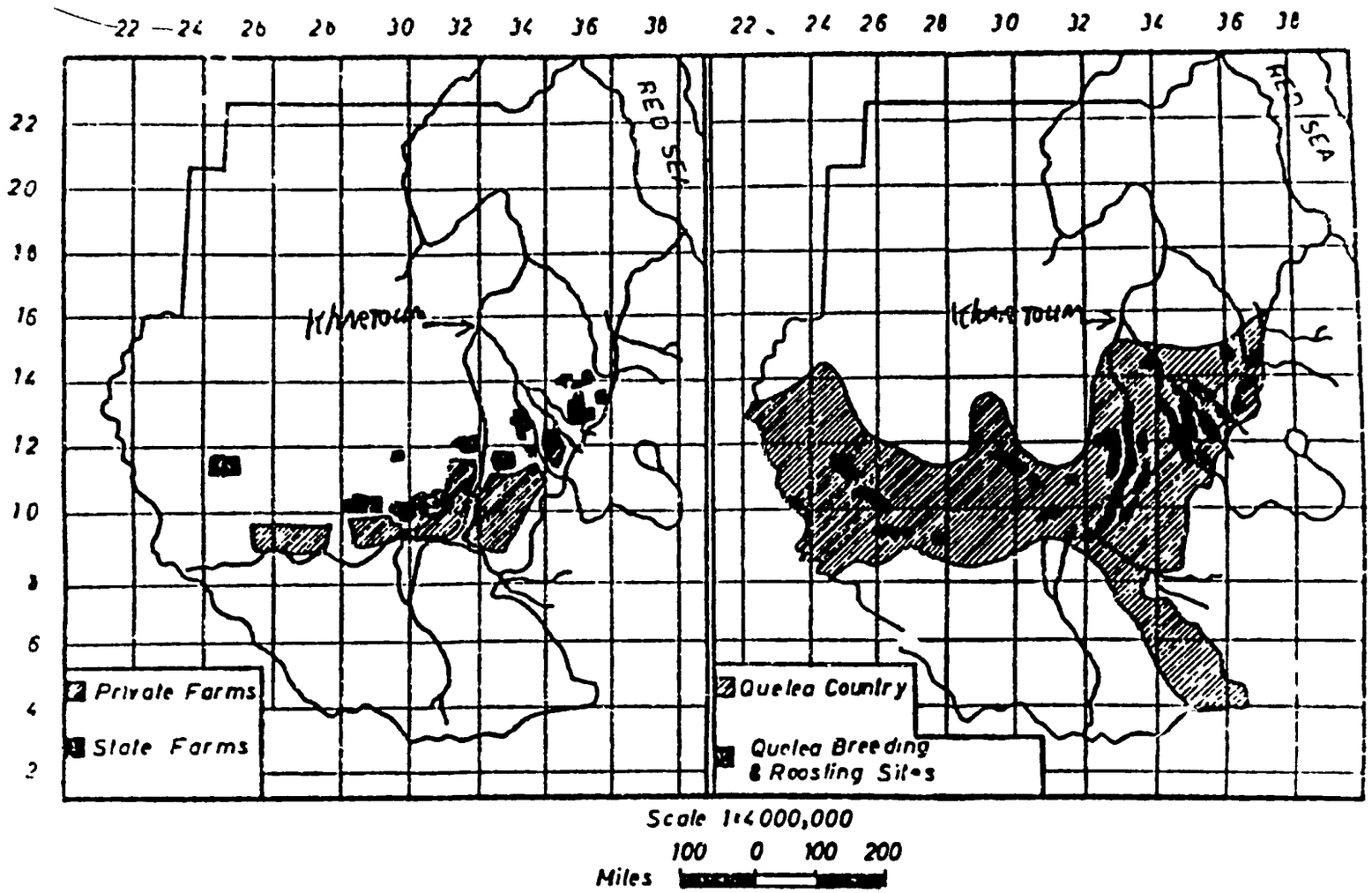


Fig. 2. Sorghum-growing area and quelea country in the Sudan (from Bashir, S. El and S. A. Bashir, undated).

Table 3. Control efforts at quelea nesting colonies and roosts, 1970-1978, by Plant Protection Department, Democratic Republic of the Sudan.

Season	Number of nesting colonies		Number of roosts	
	Located	Treated	Located	Treated
1970/71	64	31	38	24
1971/72	52	34	38	23
1972/73	65	46	44	28
1973/74	58	44	39	23
1974/75	67	51	47	33
1975/76	77	57	41	28
1976/77	60	40	30	19
1977/78	150	150	-	-

Some economic aspects

Recent investigations confirm the widely held belief that quelea are, indeed, the most destructive bird in the world. In cage studies in commercial fields near El Hawata on the Rahab River in Kassala Province, quelea were found to destroy about twice their weight in grain sorghum daily. In two days' time, 40 caged birds destroyed about 20 dabar sorghum heads, which should have produced about 150 g each. This test was replicated three times. This means that an individual 18-g quelea had the capability of destroying about 38 g of sorghum daily. At the current (November 1977) price of 37¢ U.S./kg for premium dabar sorghum, each quelea is capable of destroying about 43¢ U.S. worth of sorghum during an approximately 30-day nesting period. At this cost per bird, many methods of protecting crops or destroying quelea should prove economically feasible. For example, many simple methods, such as trapping, may be profitable. Sudanese personnel took more than 100 birds (fledglings) in a roost with two mist nets in less than 10 min. Small decoy traps have already been shown to be capable of taking large numbers of young quelea in nesting colonies. Trapping and netting in crop fields may also be profitable for quelea are very gregarious while feeding. In addition, it appears that the groups of 0.4- to 2-ha plots planted

by villagers suffer a much larger proportion of the total bird damage than the plantings in large crop schemes. Most fields in large schemes are quite distant from the extensive areas of suitable nesting and roosting cover required by the birds. On the other hand, many village fields are surrounded by such cover. Hence, simple methods of bird damage control are necessary for these small plantings.

Spraying of breeding colonies in close proximity to croplands probably has a much higher cost:benefit ratio than previously suspected. A colony of a million breeding quelea has the capability of destroying 400 or more hectares of sorghum. Fenthion (the current chemical control agent of choice) is very hazardous to avian predators and should be replaced.

Quelea in breeding colonies in the Sudan feed very heavily on grain sorghum. Our Sudanese counterparts determined, through food habits studies at the El Hawata nesting colony, that 80 percent of the diet of adult and young quelea consisted of sorghum. This is in contrast to a study in Nigeria which found only 4 percent of the quelea diet was sorghum in a year of very heavy damage.

Repellent testing

Several significant factors, pertinent to the control of quelea with repellents, were brought to light as a result of field tests. We were unsuccessful in protecting plots of sorghum with an aerial application of 4 kg/ha of methiocarb in an adhesive. However, the same concentration, when applied with a knapsack sprayer, resulted in good protection. Studies with caged birds confirmed that the aerially applied spray was ineffective. A combination of partially operative aerial spraying equipment, spray under high pressure, and excessive heat and wind apparently prevented attainment of the residue levels needed to deter quelea. Samples (sorghum heads) from both the aerially and knapsack-treated study plots will be subjected to residue analysis to determine if this is a correct assumption.

Another conclusion, reached as a result of field tests, is that dabar variety sorghum is not an easy crop to protect because: (a) it has small seeds (not unlike millet), (b) kernels do not protrude from the glumes as much as U.S. sorghum varieties (thus, less chemical would be present on the areas of kernels that quelea attack), (c) quelea attack it immediately after the flowering stage, (d) stands are quite sparse (ca 5,000 plants/ha), and (e) stands often ripen unevenly. The latter property may be useful for educating or killing birds with hand-applied sprays. For example, when the first 1 percent of the heads are in the dough stage and under bird attack while others are still in flower, these few maturing heads could be sprayed by villagers with a repellent or toxicant.

Field assessments were made to compare differences in quelea damage to sorghum in methiocarb-treated and untreated plots in Sudan.

Training

Messrs. Mohamed Hamza and Saeed Mohamed Suliman were enrolled as USAID participants in Master's programs at Bowling Green State University, Ohio, in September. Both should return to the Plant Protection Department, Bird and Rodent Section, by early 1980.

Two other staff members were nominated by USAID/DWRC to attend the Vertebrate Pest Conference in Sacramento, California, March 5-19, 1978, and receive 2 weeks' orientation at the DWRC laboratory in Colorado. These nominees were Mr. Hassan Abbas, Director, Plant Protection Department, and Dr. Albert Basta, Wad Medani Pesticides Residue Laboratory.

Academic, laboratory, and field training are an integral part of the project. This training, over the next several years, will provide a nucleus of trained personnel to handle future research, training, and extension activities in the area of vertebrate damage control research.

Cooperative programs

The quelea project will continue to communicate and cooperate with international and national organizations in eastern Africa in conducting scientific investigations on vertebrate pests.

USAID/DWRC has been invited by UNDP/FAO to participate with five East African countries in its grain-eating bird project from 1978 to 1981 by demonstrating research and control methodology and technology for direct crop protection programs. This would be a cooperative program, and USAID/DWRC biologists are looking forward to working with FAO team members, the German Bilateral Technical Assistance Agency, and the national government staffs and counterpart personnel of each of the countries involved.

This program was proposed at the IXth Coordinating Committee Meeting of UNDP/FAO in Rome, December 5-9, 1977. The three-part program for five East African countries (Ethiopia, Kenya, Somalia, Sudan, Tanzania) was proposed as follows:

1. West Germany to provide an indirect control program (i.e. suppression of quelea at roosts or nesting colonies).

2. USAID/DWRC to provide a direct crop protection program for the four countries of Ethiopia, Kenya, Somalia, and Tanzania. (Program already in operation in the Sudan.)

3. FAO personnel (ornithologist, ecologist, etc.) to handle certain applied research problems on grain-eating birds.

A project formulation mission, headed by FAO and comprised of representatives of the five East African countries, West Germany (GTZ) and USAID/DWRC, is expected to tour the five countries in February 1978 to meet with officials at national levels of government. The team will survey and review bird damage problems, discuss research and control methods technology, and counsel responsible officials of each country on research and control activities that should be undertaken.

Current status and future goals

The primary objective of the USAID/DWRC Vertebrate Pest Research and Control Project in the Sudan and East African countries has been to develop direct crop protection methods for sorghum, wheat, millet, and rice. This project has worked in Africa since 1971 through 1976 and the status for 1977 was as follows:

1. Field station terminated with EAC in Tanzania, February 1977; TDY with REDSO/EA, USAID in Kenya, March to May 1977.

2. One-man field station established in the Sudan, May 12, 1977, in cooperation with the Ministry of Agriculture, Food, and Natural Resources, Plant Protection Department, Khartoum.

3. Four field work plans/studies undertaken in Sudan, August to December 1977, by Sudanese counterparts and USAID/DWRC biologists.

4. In October 1977, quelea were furnished to the quarantine and research facility at DWRC for the following laboratory research purposes:

a. Develop radio transmitters for field use in movement studies.

b. Determine behavioral responses to chemical repellents.

c. Develop baits that provide uniform delivery of control chemicals in field applications.

d. Evaluate control by treated nest-building materials.

e. Screen alternate chemical compounds.

f. Evaluate immunological, physiological, and topical marking agents for quelea.

The following tasks have been selected for field research in the Sudan and certain East African countries for 1978-1981:

1. Development of damage assessment techniques for the principal African cereals. Ability to measure crop losses to birds is a prerequisite to evaluating effectiveness of treatments and necessary before economical control programs can be formulated.

2. Determination of optimum dosages and methods of application of chemical compounds such as bird repellents, especially methiocarb and bird-frightening agents, such as Avitrol®. This will also involve selection of attractive baits and baiting techniques.

3. Testing of mechanical devices for bird control. Trials will be conducted of control devices marketed in the U.S. and some low-cost homemade devices that might be adapted to the small fields of the traditional African farmer.

4. Refinement of trapping methods. Although traps are not likely to be an effective control method, a constant supply of fair numbers of birds will be required for experimental purposes. In addition, trapped quelea could beneficially supplement African diets.

5. Further study of quelea movements. Transmitters developed at DWRC may be a superior method for such studies. Members of the Section of Supporting Sciences are working on the problem of marking large numbers of birds, and we hope to be able to obtain much more information on long-distance movements, dispersal, and multiple breeding.

6. Contribute toward establishing a competent vertebrate pest research staff for the Sudan which would include training and institutionalization.

7. Conduct additional research on crop damage problems caused by other birds and rodents.

PHILIPPINES

The goal of this project is to reduce vertebrate damage to agricultural crops in the Philippines and other countries of Southeast Asia. Achievement of this goal is approached through adaptive research and evaluation, training, and extension activities.

Research activities were conducted on a wide variety of crops and vertebrate pest problems during the year. The studies summarized below include only those in which DWRC personnel and contract staff played a major or a supporting role. Many of the studies were conducted by graduate students as part of their degree requirements (acknowledged in parentheses). Other NCPC research on vertebrate pests included a field trial comparing the sustained baiting method

Specimens of Rattus argentiventer were collected on the island of Mindanao, Philippines, for laboratory studies of toxicants.

with use of zinc phosphide to protect ricefields from rat damage, a study on the relationships between rat damage (simulated) and yield in rice, a comparison of various bait station designs and baits for effectiveness in the field, and a study relating rat activity as measured by tracking tiles to population density of rats in uncultivated habitat.

Crown baiting with anticoagulant rodenticides protects coconut plots from rat damage for third year

A 150-ha site with a history of chronic rat problems was selected at Barrio San Gelacia, Victoria, Mindoro Oriental. Coconut palms are native varieties, 10-25 years old, from 15 to 20 m tall. Four 1-ha plots, each containing 100 trees, were chosen. One-fourth of the trees within each plot were randomly numbered for detailed studies and treatment. Two plots were treated during the first year (1975) of the study and the others served as reference areas. All plots have been treated since the second year of the study. For treatment, plastic packets, containing 0.025-percent warfarin with binlid or polished rice, were placed monthly in fronds of numbered palms. Records were kept on amounts of bait used, rat activity, numbers of fallen nuts, coconut production, copra values, and costs of rat control.

Results for the first 2 years of the study have been previously reported (Reidinger and Libay 1977). During this year, rat activity in the plots remained much lower than pretreatment levels and few fallen nuts were observed. About 36,800 nuts were harvested from the four plots, with production (8.36 nuts/tree per month) in plots treated for 3 years greater than the production (6.96 nuts/tree per month) in plots treated for 2 years. Production averaged about 2.8 times the pretreatment level. With an improved market value of copra (average ₱2.14/kg) and increased production, the estimated cost:benefit ratio for the method was 1:28.

Based on almost 3 years of evaluation, the method clearly provides long-term reduction of rat damage with excellent economic return.

Use of crown baiting with wax blocks to reduce rat damage in coconut palms

Two 1-ha study plots were selected within a large area of coconut plantations near Victoria, Mindoro Oriental. The plots are separated by over 200 m, and each contains 100 palms of a local variety. One plot was randomly selected for treatment, the other as a reference area. For treatment, 25 palms were chosen at random and are baited monthly with paraffinized cubes containing polished rice, talc, and

warfarin. The cubes are placed on palm fronds with a long bamboo pole. Monthly records are kept on bait additions, rat activity (tracking tiles and fallen nuts), and nut production.

During a pretrial survey, 164 fallen, rat-damaged nuts were counted within the reference plot and 76 within the treated plot. Rat activity averaged 82.7 percent tracked tiles in the reference area and 76.0 percent in the treated area. Rattus r. mindanensis, R. exulans, R. argentiventer, and Suncus murinus were collected in both plots. During the first 2 months after treatment, a total of 173 fallen nuts were counted in the reference plot, of which 107 (62 percent) had obvious signs of rat damage. Fifty fallen nuts were counted in the treated plots, of which only 12 (24 percent) had been damaged by rats. During the same period, rat activity averaged 48 percent tracked tiles in the reference plot and 22.6 percent in the treated plot. The trial will be continued for at least 1 year.

Rats in the coconut agroecosystem

A detailed ecological study of rats in a coconut agroecosystem was conducted on six 1-ha plots within a large plantation near Calauan, Laguna, from March through August. Palms were the Laguna variety, 9-12 m tall and from 30 to 40 years old. Information was obtained on the composition, demographic characteristics, activity and movement patterns, and damage behavior of pest species. Records were kept on coconut production in some of the plots and results were related to simulated control approaches. Field observations of damage were compared with controlled laboratory studies.

Results are currently being analyzed, but some highlights can be reported here. Trap success for R. r. mindanensis was 18.6 percent at the ground level and 0.8 percent in tree crowns. Trap success for R. exulans was 10.5 percent at the ground level and 0.2 percent in tree crowns. Approximately 77 percent of the fallen nuts had obvious signs of rat damage. This percentage was higher for larger (>11 cm; 92 percent) than for smaller (<11 cm; 41 percent) nuts. In cage trials, R. r. mindanensis damaged nuts much more readily than R. exulans and preferred button-sized (<5 cm diameter) nuts. When rats were trapped for 3 consecutive nights monthly in alternate trees within two plots, damage decreased and nut production increased. In the field, rats were most active at about 0630 and 2000-2100 (Sultan, M.S. thesis in progress).

Assessment of rat damage in corn

Several fields have been selected for detailed studies on the extent and distribution of rat damage to growing corn, and other fields have been surveyed for damage. Distributional maps of rat damage are

being prepared for the fields, and will serve as models for the simulation of several potential assessment approaches. Patterns of rat damage on ears of corn are being simulated on healthy ears to determine the relationship between weight loss and area of damage (see Sanchez et al. 1976 for preliminary results of these approaches; dela Paz, M.S. thesis in progress).

Sustained baiting with wax formulation protects rice crop in field trial

Three 1-ha plots planted to IR-26 were chosen near San Isidro, Nueva Ecija. Sustained baiting was conducted from 4 to 11 weeks after transplanting on two of the plots. In one, polished rice mixed with 0.025 percent warfarin (rice bait) was used as bait; in the other, a bait formulation containing wax, ground rice, and warfarin was used. Farmers followed traditional control approaches in the third (reference) plot.

During the period of baiting, rat activity was greatest in the reference plot and lowest in the area treated with rice bait. Bait consumption was almost 5 times greater with wax bait (total 57.1 kg) than with rice bait (12.4 kg), and feeding occurred over a longer period (5 vs. 4 weeks, respectively). Damage (percent cut tillers) was greatest in the reference plot (4.6 percent), slightly less (3.9 percent) in the areas with rice bait, and lowest (1.8 percent) in the plot with wax bait.

It appears that wax baits can be used to protect ricefields from rat damage in the Philippines, but additional studies, including those on economic benefit, are required.

Baiting in marshland reduces rat damage in adjacent ricefields

A marshy area adjacent to about 200 ha of ricefields along Lake Mainit, Mindanao, was baited with rice mixed with anticoagulant rodenticides. Bait was placed in stations on floating platforms which were distributed at 50-m intervals along two 1-km transects (20 platforms per transect). The transects were 25 and 50 m from the marshland-ricefield interface and parallel to it. Stations were checked weekly and bait and stations added as required. Baiting continued from transplant to harvest of the ricecrop in adjacent fields. Tracking tiles were placed monthly along the interface and on the baiting platforms of the transect nearest land.

Bait consumption averaged 53 kg per month during the growing season and was greatest (72 kg) during the second month. Rat activity was high (73-100 percent of the tiles were tracked) at the bait stations during the growing season. Activity along the interface, however,

dropped steadily from 67 percent tracked tiles at transplant to 5 percent tracked tiles at harvest. Damage, based on percentage of cut tillers in 10 randomly selected paddies, averaged 2 percent and the farmers harvested about 60 cavans (3 metric tons) per hectare. In a reference area, also along the marsh but 1 km beyond the baiting transects, damage averaged 19.4 percent cut tillers and the farmers harvested about 47 cavans (2.4 metric tons) per hectare. These preliminary results indicate that baiting in uncultivated habitat might be used to advantage in some situations where the untilled land serves as a major rat reservoir.

Diffusion of the sustained baiting method among Masagana-99 farmers in Laguna, Philippines

Two surveys were conducted in Laguna Province to determine the degree of awareness and adoption of the sustained baiting method among farmers who are participants in the national rice production program, Masagana-99. The first survey, conducted before the method became part of the required technology for Masagana-99 farmers, provided information on the demographic, economic, and social status of the farmers as well as information on their beliefs and practices in rat control. In the second survey, the farmers were questioned about their understanding of several critical features of the method: (1) use of chronic rodenticides, (2) continuous baiting, and (3) placement and adjustment of bait stations during the growing season. Damage surveys were used to compare rat damage in fields of farmers who had adopted the method with those who had not.

One year after implementation, only partial adoption of the method had been achieved: use of chronic toxicants in a continuous manner (rather than acute toxicants only as needed) had increased from 2 to 12.5 percent. None of the farmers were placing bait stations in paddies or adjusting numbers of stations according to the intensity of rat infestation. Of the 320 farmers interviewed during the second survey, only 60 had actually used the Masagana-99 loan for production inputs, although it was available to all participants. All of the partial adopters (40) had accepted the production loan. Most of the nonadopters said that they were not aware of the baiting method. Rat damage was lower (0.47 percent cut tillers) in fields of partial adopters than in fields of nonadopters (1.40 percent cut tillers). (Dizon, M.S. thesis in progress.)

Relationship of costs to oral toxicities of five commercially available rodenticides in the Philippines

Five common formulations of chronic rodenticides were purchased from local dealers. Three were derivatives of coumarin and two of indandione. They were mixed with polished rice according to the

manufacturers' recommendations, and fed to R. r. mindanensis in a no-choice oral toxicity trial. Twenty rats were used for each formulation and a nontoxic reference bait. The trial was repeated using rats collected with the original sample but held in the laboratory for an additional 38 days before treatment. Daily consumption and mortality records were kept until all rats receiving toxicants had succumbed.

Costs per mortality were significantly higher ($p < 0.01$) in the second trial (₱0.084/rat) than in the first (₱0.077/rat). Cost per mortality was significantly lower ($p < 0.05$) for the three derivatives of coumarin (₱0.065/rat) than for the derivatives of indandione (₱0.081/rat). No significant differences were found among compounds within each chemical type. Cost appeared highly related to consumption (total and daily), time to death, and weight of the animals.

Detection of anticoagulant resistance in Rattus r. mindanensis and Rattus argentiventer

A study was initiated to develop a simple means of detecting anticoagulant resistance in R. r. mindanansis and R. argentiventer. In preliminary laboratory trials involving several hundred rats, prothrombin times of rats treated with anticoagulant rodenticides were compared with untreated reference animals. Prothrombin times generally increased shortly after treatment and remained high for at least 72 h. Results were affected by treatment method (i.e. orally treated rats had more variable results than those treated intraperitoneally), compound, and species. Prothrombin times of resistant rats should be less affected by the rodenticides and remain similar to reference animals.

If successful, the method could serve as a simple sensor in a cybernetic system that would prolong the useful lifespan of the sustained baiting method in the Philippines. Rats would be sampled and tested (sensor) periodically in areas where the method is used; if resistance (controlled quantity) reaches an unacceptable level, baiting approaches (effector) would be altered until resistant rats again compose a low proportion of the target population. (Hoque, Ph.D. thesis in progress.)

Potential use of grease formulations to deliver oral toxicants to Rattus r. mindanensis

Considerable work has been done on the development of toxic grease formulations for rodent control. A preliminary investigation was made of the behavior of R. r. mindanensis to determine whether grease would be ingested during grooming. Approximately 2 g of vaseline, mixed with a tetracycline marking agent, was placed on the fur of

each of 15 adult rats, which were fasted for 6 h prior to treatment. The grease was smeared along the mid-dorsal line on five of the rats, along the mid-ventral line on another five, and along the mid-lateral line on the remaining rats. Grooming behavior was observed for 2 h after treatment. The animals were then sacrificed for necropsy.

All rats were readily able to remove grease, irregardless of the region to which it had been applied, and most grooming was accomplished within 15 min after treatment. When carcasses were examined under ultraviolet light, the entire length of the gastrointestinal tract (from oral vestibule to anus) flouresced intensely. Considerable amounts of grease were ingested during the grooming activities of the rats.

Assessment of rat activity at tube stations

Tubes or pipes have been used in many situations for placement of rat bait or contact toxicants. To assess use of such tube stations by field rats, a treadle switch was devised to turn on a small light whenever an animal entered. This device permitted simple night observation of rat activity at sufficient distance so that animals were not disturbed. In a preliminary test, five of the tubes were placed along the inside of a fence that enclosed a small, weedy plot. Ten prefed adult male *R. r. mindanensis* were placed within the enclosure at sunset, and observers recorded the number and length of visits to the tubes for 1 h. The test was repeated the next evening using different rats that had been fasted for 24 h and after vegetation had been removed from the enclosure. Visits to the tubes increased significantly ($p < 0.02$; Student's $t = 3.07$), from a mean of 11.8 per tube on the first night to 20.6 on the second. These devices may provide a sensitive means of monitoring rat activity at tubes.

Use of methiocarb to protect ricefields from bird damage

Two ricefields, about 1.5 ha each and separated by 1.5 km, were selected near Hinobaan, Negros Occidental. The fields, planted to IR-36, were at the milky-dough stage (surrounding fields were younger) and were receiving heavy damage from Philippine weavers (*Lonchura* spp.). One field was chosen randomly for treatment and the portion (about 0.3 ha) receiving most damage was sprayed with methiocarb at 1.7 kg active ingredient per hectare. Before spraying, the portion was divided into four quadrats and total and bird-damaged tillers were counted on 50 hills within each quadrat. The same hills were assessed for damaged tillers 4 days after treatment. Damage in the reference field was measured concurrently using a similar procedure. Observations were also made on bird activity in the fields from 2 days before treatment through the third day after spraying.

Numbers of damaged tillers increased after spraying in both the sprayed portion of the treated area and the reference area, but the increase was significantly higher (p <0.001) in the reference area. Although the total number of birds visiting the treated field appeared unchanged after part of it was sprayed, feeding activity shifted from the sprayed to unsprayed portions of the field.

Use of glue to protect ricefields from bird damage--a preliminary trial

A small ricefield (0.2 ha) was selected near Sipalay, Negros Occidental. The field, at the milky-dough stage of development, was isolated within a small valley and was being seriously damaged by Philippine weavers (*Lonchura* spp.). Numbers of weavers in the field were recorded at 10-min intervals from 0600-1600 (except 1200-1300) for 2 days before and during treatment. For treatment, a glue (made by boiling sap from two local tree species) was applied to tall weeds at 31 locations surrounding the field and at 9 locations within the field.

Forty *L. malacca* and 31 *L. leucogaster* were caught on perches during the first day after treatment. Most emitted distress calls which sometimes attracted other birds to the perches. During the 2 days before treatment, there were an average of 25.2 birds per recording interval with the most birds (56) seen in the field at 0850 and 1430-1440. Activity decreased by 97 percent to 0.85 birds per recording interval during the first day of treatment with most birds (24) seen at 0710. No birds were observed in the field during the second day of treatment. These results are encouraging and additional studies are planned.

Surveys of rat damage to sugarcane on the Negros Islands, Philippines

Sugarcane fields in 18 locations within 17 mill districts on the Negros Islands were surveyed for rat damage from April to June 1977. The fields, from 1 ha to almost 7 ha in size, ranged from the first planting to the third ratoon. Most fields were planted to Philippine 56266 or Philippine 58260, although a total of five varieties were encountered in the survey areas. The fields were assessed between 9 and 12 months after planting (harvest for ratooned crops). Information was also gathered on pest species and the nature of damage.

R. r. mindanensis, *R. norvegicus*, and *R. exulans* were seen in the fields. Damage resulted from chewing out portions of the stalks between internodes, from secondary infections when micro-organisms invaded the wounds, or by desiccation of the stalk. Within the fields examined, an average of 7.2 percent (1.6-14.6 percent) of the stalks had obvious signs of rat damage. POL (a measure of sugar

content) averaged 19.2 percent for healthy stalks and 17.2 percent for damaged stalks. (Estioko, Ph.D. thesis in progress.)

The house bat (*Scotophilus temmincki*) feeds on pest insects

A total of 454 bat specimens, representing 13 species and 5 families, were collected in Mount Makiling and adjacent areas of Laguna Province from March 1976 to February 1977. Most were collected over waterholes and swimming pools using mist nets improvised from local materials. Information, primarily for the house bat (*S. temmincki*), was obtained on distribution, seasonal abundance, altitudinal zonation, and food habits.

The house bat apparently feeds on a wide range of insect pests. Stomach contents from 107 house bats contained many pest insects, including brown planthoppers (*Nilaparvata*), green leafhoppers (*Nephotettix*), white-backed planthoppers (*Sogatella*), crickets (*Gryllus*), some grasshoppers (*Melicodes* and *Phaneroptera*), June beetles (*Leucophilus*), lady beetles (*Micraspas*), sweet potato weevils (*Cylas*), and sphinx moths (*Agrius*). Only four genera of beneficial insects were found: dragonflies (*Orthorum*), damselflies (*Riciocnemis*), assassin bugs (*Caunus*), and honeybees (*Apis*). House bats are commonly seen foraging over farmers' fields at dusk in the Philippines. Their economic role in the agroecosystem warrants additional study. (Rubio, M.S. thesis in progress.)

Training

During this year, staff members provided resource lectures, workshops, or demonstrations on rodent control to over 3,000 government extension personnel and key farmers from the Philippines and other countries. In addition, more than 300 visitors from many countries were briefed on the Center's activities, given technical assistance in the form of literature on rodent control, or advice in program planning. Numerous requests for technical information on rodent control were filled with Center publications or copies of appropriate material from our library.

Four technicians from Thailand spent about 1 week at the Center and received information on research techniques for vertebrate pest studies, and discussed research findings. Their visit was sponsored by the Thai-German Rodent Control Program. Five technicians from Bangladesh visited our Center chiefly to discuss latest research findings.

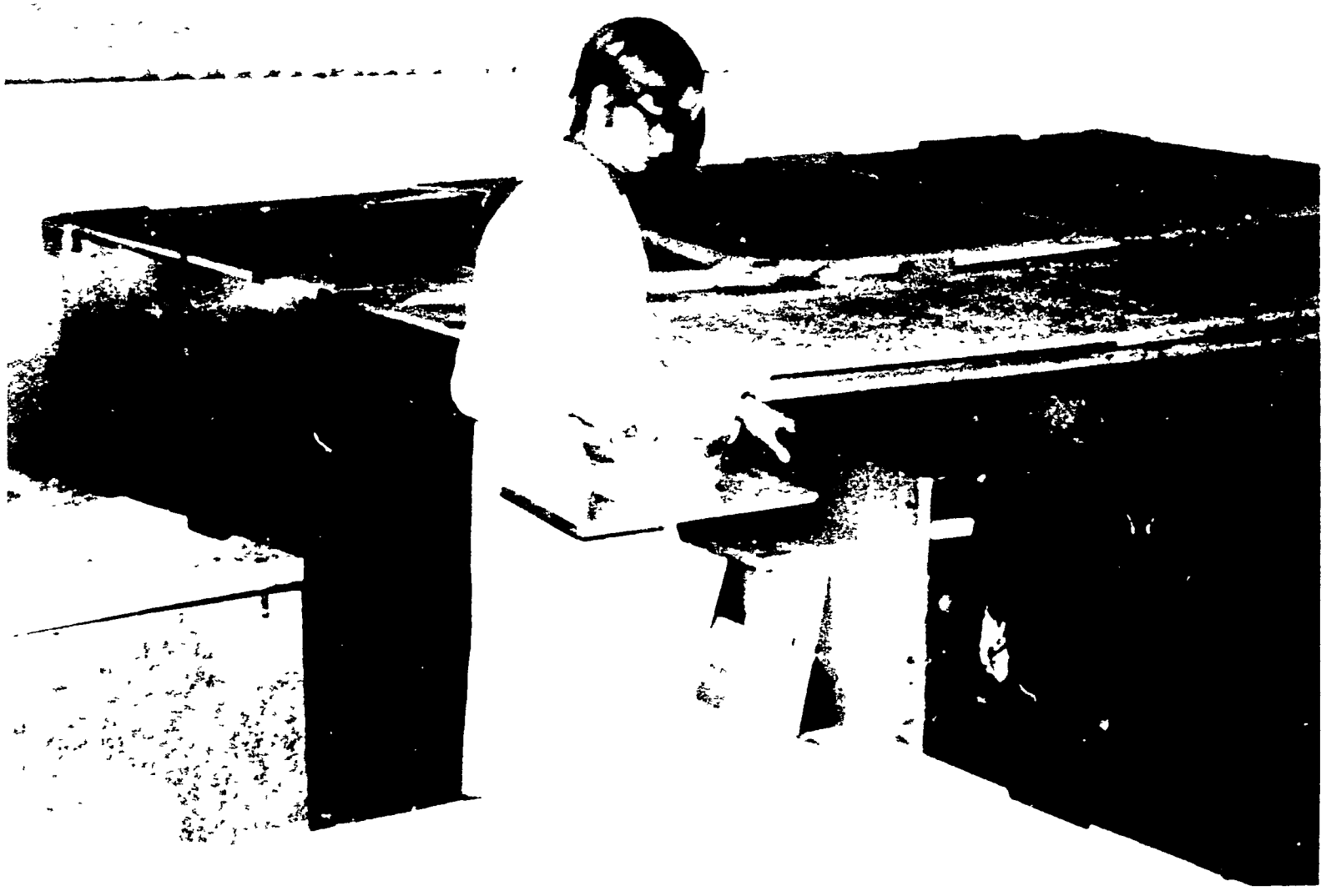
Two Center staff members spent 6 months each in the United States for advanced training in pest management. One trainee took formal course

work in biostatistics at Oregon State University, and visited, consulted, or participated in field studies involving vertebrate pests at the DWRC, Stanford University, and the DWRC field station in Davis, California. The other, under the auspices of the University of California at Berkeley, observed research and operational programs in integrated pest management in California, Texas, and Minnesota, and the DWRC. Both trainees were sponsored by the USAID.

Three staff members continued pursuit of Ph.D. degrees, one under a PCARR grant, the other two with UPLB reduced-fee privileges. All have completed required course work and are conducting thesis research. Six additional students, all working on M.S. degrees with NEDA support, are completing thesis studies. One student, under the Department of Forestry, completed his thesis on feeding behavior of bats and received his M.S. degree in September.

Several Center staff members hold joint appointments with departments of the University of the Philippines at Los Baños and act as graduate advisors or instructors. During this year, they taught or helped teach courses in Vertebrate Pests and Crop Protection. Some sessions were held in the classroom and laboratories of the Center, and students used equipment and facilities located at the Center to conduct individual research projects.

One staff member attended the "International Controlled Release Pesticides Symposium" at Corvallis, Oregon, from August 22-24. He also attended meetings at the Institute of Mathematical Statistics, Stanford University, sponsored by the American Statistical Association and the Western North American Region, from June 22-24. One staff member and three students of the Center served as resource speakers at the "2nd Regional Training Seminar on Field Rat Control and Research" held at Manila and Maligaya, Nueva Ecija, from March 16-25. The seminar was jointly sponsored by the Philippine-German Crop Protection Programme and the BPI. Center staff and students participated in the symposium entitled "Small Mammals: Problems and Control" held at the NCPC, from December 6-8. The symposium was jointly sponsored by BIOTROP (Bogor, Indonesia) and UPLB.



The response of Rattus rattus mindanensis to odor-enhanced bait was studied by exposing test materials to groups of rats in enclosures.

SUPPORTING RESEARCH

The Section of Supporting Sciences, along with other sections of the DWRC, provide backup research in support of field activities on vertebrate damage problems. A staff of specialists in such fields as toxicology, animal behavior, physiology, bioelectronics, and chemistry, utilizing modern scientific instrumentation and facilities, provide the capability for laboratory research into many facets of a vertebrate damage problem. It would be impractical, if not impossible, to duplicate this team of specialists and specialized equipment at the overseas field stations. DWRC research activities pertinent to, or in support of this project are summarized in the following reports.

Toxicity of commercial rodenticides to agricultural rodents in developing countries

Little information is available on the toxicity of commercial rodenticides to the variety of rodent species that occur as agricultural pests in developing countries of the tropical and subtropical regions. In several instances, operational control programs are actually underway using chemicals which may be inappropriate or ineffective against the problem species. The increasing interest in vertebrate pest problems and numerous requests for advice and assistance on pest situations in which there is little or no toxicological information for the species involved, clearly indicates the need for development of such information. As a first step in improving this situation and establishing an information base, we propose to evaluate a selection of commercial rodenticide concentrates with potential for small-farm agricultural rodent control programs in developing countries. These chemicals might include, but would not be limited to, warfarin, diphacinone, chlorophacinone, coumachlor, difenacoum, ICI-PP581, bromodialone, Fumarin, Pival, coumatetralyl, Vacor, zinc phosphide, norbormide, red squill, fluoroacetamide, and sodium monofluoroacetate. Species for which information on the acceptance and efficacy of these compounds is of highest priority include *R. argentiventer* (Southeast Asia); *Bandicota bengalensis* (South Asia); *Arvicanthis niloticus*, *Mastomys* spp., and one or more gerbilline species (Africa); and *Sigmodon hispidus*, and one or more unidentified cricetid species (South America). Reference bioassays using the same standard methods will be conducted using *R. norvegicus*, *R. r. rattus*, *R. r. mindanensis*, *R. exulans*, and *Mus musculus* on which better baseline data are available for most compounds. The importance of other species may be recognized as we become more informed on crop damage problems in Africa and Latin America.

These tests will provide a basis for deciding areas where primary research should be directed toward development of suitable delivery systems or where field trials of sustained baiting or other rodent control techniques may proceed. They will also provide a basis for recognizing species against which currently available rodenticides are not effective, as formulated, and where primary research should be directed toward improved formulation or identification of new candidate rodenticides. Lack of facilities and trained personnel in most of the countries where these species occur and the desirability of accomplishing this task using standardized procedures and materials, justifies completing such work at the Denver Center. Follow-up work involving more detailed evaluation of field application methods or improved formulations will be carried out in representative problem areas in conjunction with cooperative field projects or training programs to be established under the AID PASA.

The chemicals listed in Table 4 represent about one-half of those proposed for testing. Warfarin is the only chemical tested as a chronic rodenticide. All others were tested as acute toxicants. Thus far, the data have not revealed any surprises. We have experienced some laboratory acclimatization problems with cotton rats. Testing on other species will be accomplished as animals become available.

Summary of rodenticide tests on three chemicals from Abbott Labs

Last year, Abbott 40458 was found to be very toxic when gavaged to Norway rats, but its effectiveness in baits was not good. Two analogs of Abbott 40458 were evaluated in baits but neither was effective, and concentrations of A-40458 as low as 0.125 percent caused bait shyness (Table 5). Apparently, these chemicals have a rapid onset of action or produce taste aversion which prevents rats from ingesting lethal doses. These data indicate that A-40458 is not suitable as a rodenticide.

Table 4. Toxicity of rodenticides.

Common name (Scientific name)	Chemical, concentration tested (%)															
	1080 (0.2)		1081 (2.0)		ZnP (2.0)		Norb (2.0)		RH-787 (2.0)		PP-581 (0.002)		DRC-4575 (1.0)		Warf (0.025)	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Gerbil	--		--		5/5	5/5	--		--		--		--		--	
Wild Norway rat (*Rattus norvegicus*)	--		5/5	4/4	--		--		--		5/5	5/5	5/5	4/4	5/5	5/5
Cotton rat (*Sigmodon hispidus*)	4/5	2/5	--		5/5	5/5	0/5	0/5	4/4	4/4	5/5	5/5	6/6	3/4	--	
Ricefield rat (*R. r. mindanensis*)	3/5	2/4	10/10	--	5/5	5/5	3/10	--	10/10	--	10/10	--	10/10	--	10/10	--
Ricefield rat (*R. r. argentiventer*)	--		--		5/5	5/5	--		10/10	--		--	10/10	--	--	

1080 = sodium monofluoroacetate
1081 = fluoroacetamide
ZnP = zinc phosphide
Norb = norbormide
RH-787 = Vacor•
PP-581 = brodifacoum
DRC-4575 = benzenesulfonic acid (3-amino-2,4,6-trichlorophenyl) methylene hydrazide
Warf = warfarin

Table 5. Free-choice feeding tests with Abbott chemicals in wild Norway rats (Rattus norvegicus).

Chemical	Concentration	Sex	No. dead/No. tested
A-40458	1%	M	4/5
		F	2/5
	0.5%[1]	M	2/5, 2/5
		F	3/5, 3/5
	0.25%	M	1/5
		F	1/5
	0.125%	M	2/5
		F	0/5
A-40145	1%	M	1/5
		F	0/5
A-40147	1%	M	0/5
		F	0/5

[1] This concentration tested twice, in June 1976 and December 1977.

Evaluation of adhesives for foliar application of methiocarb

One approach to alleviate bird damage to agricultural crops is through the use of nonlethal chemical repellents. One such chemical that has shown potential is the avian repellent methiocarb, 4-methylthio-3,5-xylyl N-methylcarbamate. It has been field tested throughout the United States on various grain crops and found effective against red-winged blackbirds (Agelaius phoeniceus). Preliminary field tests in Africa and laboratory studies at DWRC indicate that methiocarb can reduce damage by quelea (Quelea quelea). However, there is a need to prolong the effective duration of this and

other chemical repellents on grain crops, especially in areas where the crops are exposed to rainfall during the critical period of greatest bird predation.

Five commercially available foliar adhesives will be tested for potential use on sorghum and other grains. Each adhesive will be formulated with methiocarb and sprayed onto mature grain sorghum heads. Each treated head will then be exposed to simulated rainfall (0, 0.5, 1, 2, and 3 in). Residue analyses will be conducted on each experimental sample. Those showing potential will be further tested with caged quelea birds.

To date, treatment of grain heads and exposure to simulated rainfall has been completed. Results of the chemical analyses and evaluations with caged birds will be presented in the 1978 Annual Report.

Behavioral response of quelea to methiocarb: imitated feeding behavior

Flocks of quelea cause extensive damage to grain crops (i.e. millet, sorghum, rice, and wheat) in many African nations. Published reports have described their social, roosting, nesting, and feeding patterns in detail. However, no descriptions have been published regarding quelea behavioral responses to the presence of birds affected by fright-inducing or repellent chemicals such as methiocarb. If quelea do reliably imitate the feeding patterns of such affected birds, perhaps ingestion of treated grains by only a few members of a depredating flock would produce avoidance behaviors in other nontreated birds.

We found that unexposed birds did exhibit changes in preference behavior for colored grains that tended to conform to the behavior of birds exposed to methiocarb. These preference changes are shown in Table 6. The mean preference change was 35.1±17.5 percent, which is statistically reliable ($t = 2.72$, df = 9, $p < 0.05$). Thus, the data tend to predict that a proportion of quelea in a depredating flock could be repelled by imitating the changed feeding patterns of birds affected by methiocarb.

Table 6. Preference behavior of 10 quelea for green-colored millet before and after pairing with methiocarb-exposed birds.

Bird number	Sex	Before pairing (mean % preference ± SD)	After pairing[1] (mean % preference ± SD)
14	F	100.0± 0.0	53.4±31.3
12	F	99.6± 1.1	77.6± 7.0
22	F	99.6± 1.1	25.3±16.3
41	F	99.1± 1.6	67.8±18.7
52	M	98.5± 4.2	66.8±20.0
18	F	98.1± 3.2	62.4±24.8
51	M	82.4±19.1	59.0±25.9
42	M	58.5±42.7	17.8±12.2
43	F	0.0± 0.0	37.0±45.7
63	F	0.0± 0.0	8.0±13.7

[1] Birds 43 and 63 were paired with quelea exposed to methiocarb on red-colored millet; all other birds were paired with quelea exposed to methiocarb on green-colored millet.

Investigations of variables affecting ultrasound repellency in *Rattus r. mindanensis*

Rats often damage food stored in warehouses, grain elevators, and other structures where the use of rodenticides may be strictly regulated or prohibited. In these situations, rat-proofing procedures must be carried out, and the resident population of rats must be eliminated using costly, nonchemical methods (e.g. trapping). Although many commercially manufactured ultrasonic devices for repelling rats have been marketed, their efficacy in semifield situations has not been adequately assessed. Two ultrasound tests were conducted during the calendar year. One involved a comparison of ultrasound repellent effects in Norway vs. ricefield rats. The other test

was an assessment of an experimental, variable-frequency device with ricefield rats.

Rat activity and food consumption measures during a 10-day trial with R. norvegicus are listed in Table 7, with comparable measures taken on a previous trial with R. r. mindanensis. As shown, the 20-kHz generator effectively repelled ricefield rats, but none of the generators appeared to affect the activity or food consumption of Norway rats. Possible species differences in sensitivity to 20 kHz ultrasound could explain these results, but more work is required to verify the reasons for the observed species differences.

Table 7. Food consumption and activity of two species of rats tested under identical conditions with three ultrasonic repellent devices.

Ultrasound device	Food consumption (g/day)		Activity (photocell breaks/day)	
	Rattus norvegicus	Rattus r. mindanensis	Rattus norvegicus	Rattus r. mindanensis
Control (no sound)	43.9±4.5	90.3±1.7	178.3±17.4	133.6±13.8
20 kHz	49.7±3.7	0.0±0.0	580.2±54.3	1.2± 0.6
20-30 kHz	78.7±4.7	44.7±6.6	297.1±31.2	173.5±27.5
40 kHz	50.8±8.6	38.5±4.2	160.0±36.2	160.1±18.2

Results obtained with the variable frequency device are given in Table 8. Food consumption decreased slightly, but a 40.9-percent decrease in rat activity resulted from the use of this device. In previous trials (Table 7), a 20-kHz device had completely suppressed feeding activity of R. r. mindanensis under very similar test conditions. The slight change in intensity at 20 kHz for the two devices (118 dB vs. 116.5 dB) is probably not great enough to account for the different results. Apparently, the variable-frequency (Sonitron) model produced ultrasonic sound patterns that caused less alarm or pain to the rats than the 20-kHz (Urie One) device. In later tests which simulated operationally realistic sound intensities (ca 85 dB), no effects on the behavior of either species were evident with any of the units.

Table 8. Performance of a variable frequency (15-25 kHz) ultrasonic device tested with *Rattus r. mindanensis*.

Test days	Food consumption (g/day)		Rat activity (photocell breaks/day)	
	Sonitron chamber ($\bar{x}$ ± SD)	Control chamber ($\bar{x}$ ± SD)	Sonitron chamber ($\bar{x}$ ± SD)	Control chamber ($\bar{x}$ ± SD)
1-3	69.3±17.2	85.7±12.1	61.3±22.0	50.7± 6.5
4-6	78.7± 4.5	113.3±15.1	108.3±51.7	358.3± 60.2
7-9	73.0± 8.5	112.3± 8.4	124.3±62.2	321.3± 91.1
10-12	67.3±10.2	80.3±47.4	133.3±72.5	331.7±177.0
13-15[1]	76.7± 5.8	58.7± 3.1	186.3±44.1	141.7± 16.2
16-18[1]	71.7± 1.5	53.7±11.0	159.3±33.2	103.7± 9.5
Grand means ± SD	72.8± 8.9	84.0±30.1	128.8±58.6	217.9±145.1

[1] Positions of the activated Sonitron Unit reversed on these days.

Laboratory tests of the repellent activity of selected chemicals for protecting corn from damage by cotton rats (*Sigmodon hispidus*)

In certain farming areas of Latin America, the cotton rat (*S. hispidus*) causes extensive damage to early growth corn plants (i.e. <6 in high). Although higher protein corn varieties are being developed to increase the nutritional standards of these nations, rodent damage is likely to hinder these agricultural advances. For example, in many regions damage is so severe that fields must be replanted several times before adequate corn stands can be raised. This research was aimed at development of repellent chemicals that will prevent rodent damage to young plants. Several candidate

repellents (Di-Syston, Furadan, methiocarb, Arasan, dimethoate, and Guthion) were evaluated. Both Di-Syston and Furadan at 0.75-percent concentrations on wheat seeds, produced over 90 percent repellency during initial tests (Table 9).

Table 9. Wheat seed bioassay test results ($\bar{x}$ ± SD).

Chemical	Uneaten seeds/period (based on 25/period fed)	Percent repellency
Di-Syston	22.6± 2.7	93.3± 6.2
Furadan	23.1± 1.5	92.5± 6.0
Methiocarb	21.9± 1.8	87.1± 7.2
Arasan	18.3± 5.3	75.7±20.8
Dimethoate	13.8± 6.5	55.3±25.8
Guthion	12.9±11.1	51.6±44.5

However, when these same chemicals (1 percent wt/vol) were surface coated on growing corn plants, no decrease in plant cutting by rats was shown (Table 10).

Table 10. Number of corn plants (twenty plants offered to each group/day) damaged per day for the control and repellent treatments.

Test days	Chemical treatment				
	Rhoplex AC-33 Binder (control)	Di-Syston (seed)	Di-Syston (soil)	Furadan (seed)	Furadan (soil)
1	6	19	15	19	19
2	2	4	5	10	12
3	5	4	10	17	9
4	2	4	9	9	17
5	4	3	9	9	11
Total number damaged out of 100 plants	19	34	48	64	68

Although a separate no-treatment control group was not tested, rats in the Rhoplex AC-33 Binder group damaged the least number of corn plants, possibly indicating that the taste or texture of plants treated with this product could have caused this response. Later enclosure tests indicated that the repellent effect of either Di-Syston or another aversive drug (lithium chloride at 1 percent wt/vol) could be somewhat enhanced by adding sweet-tasting compounds to the plant treatment mixture (Table 11).

Table 11. Behavioral response of cotton rats exposed to corn plants treated with Di-Syston and lithium chloride in combination with glucose and saccharin.

Treatment	Feeding time (min)	Stem clipping	Leaf eating	Digging	Seed or root eating	Total feeding period (min)
Untreated corn	11.6	14	16	18	6	59.5
Di-Syston Day 1	30.5	9	28	28	9	394.1
Di-Syston Day 2	20.2	10	39	19	4	427.0
Di-Syston Day 3	25.6	13	46	15	3	512.4
Di-Syston+sacch.	7.6	8	13	30	0	320.6
LiCl+Glu+sacch. Day 1	37.0	7	16	7	0	389.9
LiCl+Glu+sacch. Day 2	21.3	8	8	44	0	499.8
LiCl+Glu+sacch. Day 3	15.0	6	5	77	0	421.3
LiCl+Glu+sacch. Day 4	44.7	13	17	0	0	485.8

Olfactory response of rats to rice oil aroma

An additive of rice volatiles effectively increased acceptance by *R. r. mindanensis* in earlier tests with a 0.2-percent zinc phosphide bait. One previous odor preference test for the rice additive indicated that individually tested rats visited a reservoir of rice volatiles more often than one containing Purina laboratory rat chow odors. The current report is an extension of this work. The main objective was to determine whether or not taste experience is a critical factor affecting ricefield rat attraction to rice oil odors. Preliminary data are given in Table 12.

Table 12. Effect of taste experience on olfactory attractant responses to rice bait by *Rattus r. mindanensis*. All values are $\bar{x} \pm$ SD for 4 days.

	Group I (no taste experience)	Group II (taste experience)
Percent preference for untreated rice	50.9±16.5	48.5±22.2
Percent preference for odor-treated rice	44.4±15.6	83.7±15.5
Percent feeding time/visit at odor-treated bait station	36.3±17.5	78.1±14.8
Total visits to odor-treated bait station	19.0± 4.6	24.7±12.2
No. visits where feeding occurred	9.0± 5.0	8.6± 4.7

Both groups displayed similar preference patterns during the baseline periods indicating that right-left bait station alternation eliminated position biases for both groups. During the odor treatment period, however, only the second group, that had taste experience with rice oil, showed a consistent preference for the rice oil odor

bait station. Likewise, this group showed a large increase in feeding time per visit when compared to the animals that lacked such experience.

Both results (increased consumption and increased feeding time) tend to support the hypothesis that taste experience with an additive is necessary before odor-attractant properties develop. On the other hand, the taste experience group did not exhibit large changes in total number of visits to the odorized bait station regardless of whether feeding occurred or not. Again, food consumption and feeding times were more sensitive measures of odor attractant quality than visitation measures. These data suggest that the additive produces conditioned odor attractiveness only after rats are allowed to taste oil-treated baits. Whether or not a larger portion of the population could be attracted to rice oil-treated bait stations is another question that can be adequately answered only through field testing.

Bait consumption patterns of ricefield rats fed select concentrations of warfarin and zinc phosphide in rice

A major problem affecting the use of acute rodenticides is bait shyness. This refers to the decreased acceptance of a rodenticide bait once sublethal quantities have been consumed. To date, studies designed to quantify aspects of bait shyness have been greatly limited by food intake measurement procedures. Without exception, these studies have involved the use of 24-h bait consumption measurements--data which obscure the changes in a rat's feeding pattern as it eats and experiences the initial effects of a rodenticide. Additionally, although numerous studies of conditioned taste aversion have been reported, these typically involve the use of injection techniques, a procedure that does not allow inferences regarding natural onset of shyness due to oral ingestion of baits.

Using a device which records individual rat food consumption at 1-min intervals, a study is underway to compare the feeding patterns of ricefield rats fed a ground-rice bait containing warfarin and zinc phosphide. The work represents a continuation of that described in the 1976 Annual Report.

Table 13 shows mean bait consumption and spillage for the zinc phosphide, warfarin, and cellulose (control) groups. As shown, these measures differed greatly between groups and across the 3 days of measurements. Total consumption of zinc phosphide and cellulose were similar, generally ranging between 14 and 17 g per day; whereas consumption of the warfarin bait was much lower, ranging between 6.07 and 9.34 g per day. Conversely, daily spillage was generally

greatest for rats given zinc phosphide bait; the highest single-day spillage (25.05 g) occurred for the warfarin-baited rats on the third day of treatment. Together, these measures reflect the sensitivity of ricefield rats to adulterated food. The typical consumption and low spillage values recorded for the 5-percent cellulose mixture further support this point.

Table 13. Mean bait consumption and spillage for ricefield rats fed mixtures of ground rice containing zinc phospide (1 LD_{50} unit per day), warfarin (1 LD_{50} unit per day), or 5% cellulose (control).

Group	Bait Consumption (g)			Spillage (g)		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Zinc phosphide	16.68	9.85	16.00	11.61	13.33	12.69
Warfarin	6.07	8.80	9.34	2.46	1.35	25.05
Cellulose (control)	14.91	14.14	17.90	.03	.99	2.16

Table 14 lists mean daily feeding times and mean consumption per minute for animals in each group. Rats on warfarin bait fed about half as frequently as those on zinc phosphide and cellulose, and had the lowest bait consumption. All rats fed for only a short portion of each 24-h period; average feeding times ranged from 43 min (warfarin - Day 3) to 90 min (cellulose - Day 2) per day.

Table 14. Feeding time and bait consumption of ricefield rats fed bait containing 1-LD_{50}-unit-per-day mixtures of zinc phosphide, warfarin, or a control bait containing 5% cellulose.

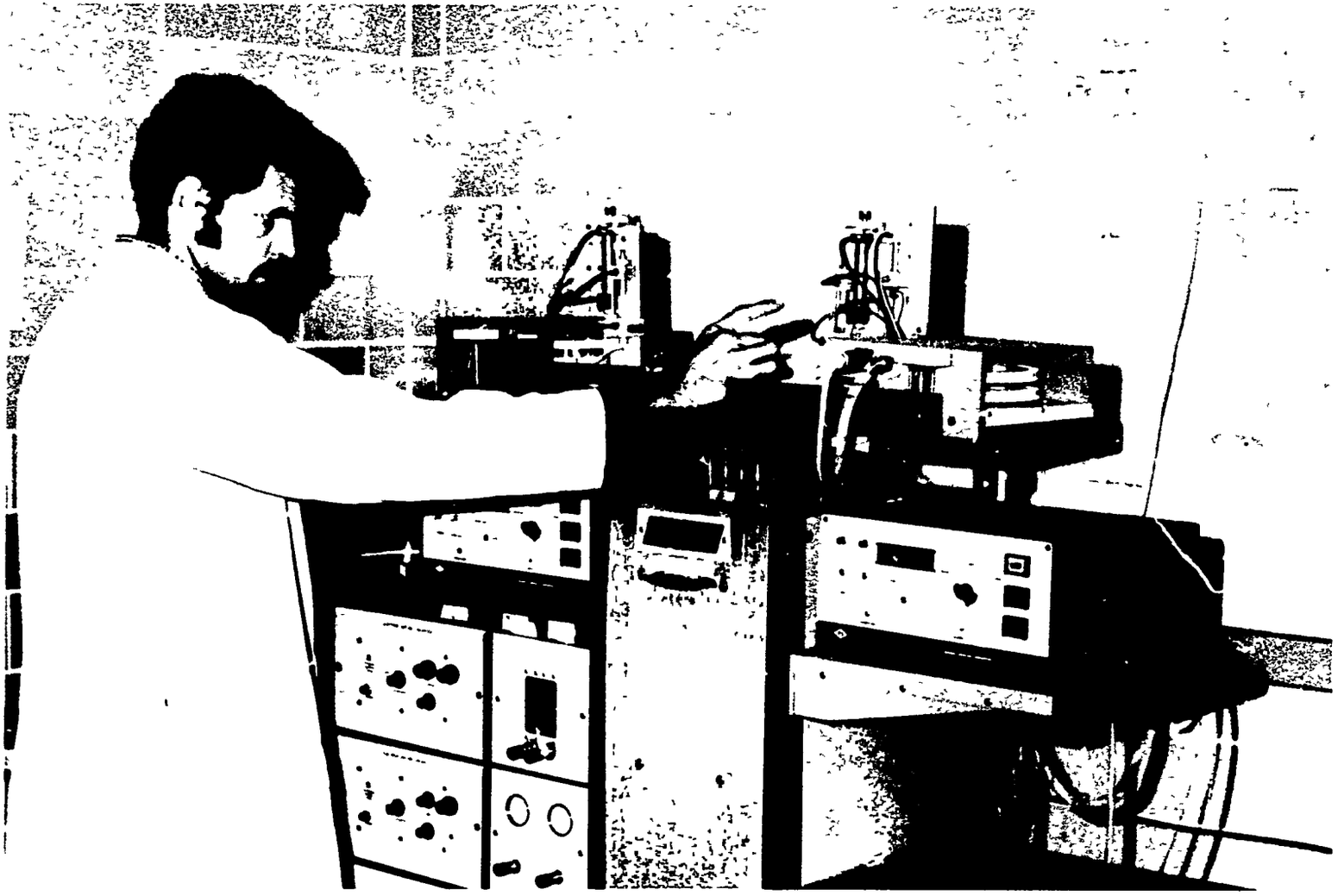
Group	Mean feeding time (min)			Mean bait intake (g/min) per interval (g)		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Zinc phosphide	85	55	65	.195	.180	.245
Warfarin	37	51	43	.164	.173	.256
Cellulose	85	90	49	.196	.156	.300

A typical nocturnal feeding pattern was observed in each test condition. More importantly, however, feeding patterns of rats receiving zinc phosphide and warfarin were characterized by intermittent, 1-min samplings (<.1 g) of the bait, whereas the control group ate several 5- to 10-min "meals" (.5-1.5 g) separated by 1- to 2-h nonfeeding intervals. This "nibbling" pattern provides a means for rats to sample the bait in small quantities without receiving a lethal dose. Further work to analyze the minute-by-minute feeding patterns of rats should provide an improved procedure for studying new means of reducing bait shyness.

An analytical method for residues of warfarin in water, soil, and rice plants

Warfarin is being used experimentally to control rice rats in the Philippines. The project requires analysis of rice plants, soil, and water for residues of warfarin. We devised a method for the determination of 0.01 ppm warfarin in water and 0.1 ppm in soil and plants.

The recoveries (and coefficents of variation) for replicate analyses of fortified soil samples (n = 5) were 104 percent (14 percent) at the 0.1-ppm level and 90 percent (6 percent) at the 1-ppm level. Recoveries were 70 percent (4.9 percent) at 0.1 ppm and 71 percent (7.8 percent) at 1 ppm for rice plant samples (n = 3), and 87 percent (15 percent) and 85 percent (6 percent) at 0.01 ppm and 1 ppm, respectively, for water samples (n = 5). Higher sensitivities were obtained for water samples than for soil and plants because they contained less organic material which complicates the analysis. Although the field samples from the Philippines will differ, with



Gas chromatography was used to determine pesticide residues in samples of soil and plant material from treated fields.

respect to chemical background and interference, from the samples used for the developmental analyses, similar recoveries and precision are expected.

Nonlethal electric barriers for animal damage control

Preliminary tests using nonlethal, high-voltage electric barriers to halt the ingress of rats into ricefields have shown positive results. The results from field trials in the Philippines in 1976 were generally favorable, but one problem encountered was the reliability of commercial fence chargers. Hence, various fence chargers were examined in 1977 and their output characteristics measured. It now appears that devices designed with solid-state circuitry have more desirable characteristics than electromechanical chargers in a high-humidity climate, such as that of the Philippines. Solid-state fence chargers will, therefore, be used for the next field trial scheduled for 1978.

Taste repellency vs. polyphenolic content in bird-resistant sorghum

Bird-resistant sorghums are one of the nonlethal methods used in recent years in an attempt to prevent bird damage. Although certain physical characteristics of sorghum heads may contribute to bird resistance, the major effort has been in developing varieties high in polyphenolic tannins. These bird-resistant varieties offer considerable crop protection in areas where alternate foods, such as grass or weed seed, are available. However, this benefit does not come without a price; high tannin content decreases both palatability and nutritional value of sorghum grain. This becomes a major concern in regions where sorghum is one of the staple food items for the human population.

There is some evidence that tannin content may not be the most important chemical basis for bird resistance. Some varieties with intermediate tannin content are highly bird resistant, yet have excellent food qualities. The possibility that bird-resistant varieties with good food quality may already exist or be developed, or that a highly effective repellent for crop application might be discovered, has led to this area of research. This study involved a comparison between the polyphenolic content and bird preference response for 15 bird-resistant varieties of sorghum.

Data from the polyphenolic analysis and preference tests are given in Table 15. The most noticeable factor in the table is the difference in preference under full-light and darkened conditions. With only one exception (hegari on quelea) for the preference measurement and one (AR-3009 on quelea) for the paired *t*-test, the values indicate a

Table 15. Quelea and red-winged blackbird preference to 15 pelleted bird-resistant varieties of sorghum of different polyphenol content (individual cage tests, five birds per treatment).

Variety	Polyphenols (mg/100 mg)	Quelea				Red-winged blackbird			
		Mean % preference		t-test		Mean % preference		t-test	
		Full light	Darkened	p Full light	p Darkened	Full light	Darkened	p Full light	p Darkened
WGF	4.67	0.6	17.8	0.0019	0.027	1.1	37.2	0.00024	0.20
RA Bird Go-68	4.61	2.6	4.3	0.00043	0.0012	10.7	43.0	0.00062	0.76
IS-2403c	4.30	6.2	19.3	0.054	0.012	11.5	29.7	0.018	0.015
G-516	3.79	7.0	13.9	0.00083	0.00086	6.2	34.3	0.00034	0.008
BR-54	3.59	3.8	17.4	0.00034	0.031	7.3	26.2	0.00062	0.027
AR-3009	3.47	35.6	47.6	0.55	0.11	23.2	38.3	0.022	0.22
AR-3005	3.21	10.8	21.1	0.0027	0.016	2.9	27.7	0.00063	0.093
AKS-614	3.07	4.8	26.1	0.0012	0.01	11.1	40.3	0.0034	0.031
IS-2266c	2.77	26.4	50.4	0.092	90.0	14.8	45.4	0.0055	0.31
ROKY-78	2.74	26.5	44.1	0.092	0.074	4.3	49.0	0.00077	0.65
Hegari	2.62	51.5	36.6	0.26	58.0	2.1	38.7	0.00031	0.19
IS-2801c	2.35	21.9	36.6	0.016	12.0	11.0	52.3	0.016	0.68
IS-3063c	2.03	29.0	38.6	0.082	22.0	7.0	38.2	0.001	0.20
TAM-2566	1.96	21.1	51.8	0.96	15.0	14.6	34.4	0.021	0.10
BRAVIS	0.54	25.6	53.5	0.20	26.0	51.3	51.6	0.87	0.74

greater acceptance of bird-resistant varieties under darkened conditions than under full light. Apparently differences in color between control and bird-resistant pellets were influencing the preference response under full-light conditions. However, the variation of preference with respect to food color reveals the importance of the taste component. Some light-colored varieties were more aversive than darker ones because of their higher polyphenolic concentrations. Testing under darkened conditions minimized the effect of visual cues, especially for quelea.

The negative correlation between polyphenolic content and preference was statistically significant ($p < 0.05$) in all cases except for blackbirds under darkened conditions. This indicates that these compounds elicit taste repellency. There is good evidence that composition of polyphenolics may be more important than total concentration. The relative preference under darkened test conditions indicates that quelea are more responsive than red-winged blackbirds to taste repellents.

Color discrimination of quelea under reduced lighting conditions

Food familiarity is a powerful influence on preference behavior. Physical factors (e.g. color, size, hardness, texture, etc.) of a food are so influential that birds will often not respond to a new food. Therefore, in a paired comparison, any differences may not be totally attributed to chemical additives. The previous report discussed quelea preference for 15 varieties of bird-resistant sorghums which are high in repellent polyphenols. Test pellets for the various varieties ranged in color from yellow to dark brown. The birds were adapted to a red, bird-susceptible variety (low in polyphenols) with a coloration approximating the lighter pellet. None of the varieties, however, had the exact coloration of the control and the correlation of repellency values with polyphenolic content (Table 15) indicated that visual cues associated with food familiarity were influencing results. This study was designed to evaluate the extent of this influence.

The results of the visual-effect study are given in Table 16. Conditioned birds had a mean acceptance of 97.1 percent for green-colored millet under lighted conditions and analysis by paired t-test showed that the difference in consumption due to color treatment was highly significant ($p = 2 \times 10^{-5}$). Under darkened conditions, the mean preference for the same birds was 54.5 percent ($p = 0.14$) meaning they could not discriminate between color choices. This was comparable to the results for control birds under darkened conditions (preference = 47.5 percent; $p = 0.28$). Under darkened conditions, the standard deviation was substantially higher for both groups of birds than it was for conditioned birds under full light. Thus, it

appears that preference due to visual cues was eliminated under the darkened conditions. Furthermore, the lack of any taste preference response for control birds indicates that the response of the 10 conditioned birds was mainly visual.

Table 16. Quelea preference for green- vs. red-colored millet under two lighting conditions.

Conditioned birds			Control birds	
	Lighted	Darkened		Darkened
Bird No.	Preference (% ± SD)		Bird No.	Preference (% ± SD)
65	98.3± 3.2	61.8±40.7	112	48.4±46.3
170	99.6± 1.3	47.6±51.8	64	44.3±49.9
86	99.6± 0.9	61.1±44.1	71	40.7±41.0
95	97.7± 2.6	67.1±42.6	150	58.8±28.9
113	96.9± 9.1	47.4±51.9	180	44.7±51.7
136	99.1± 1.6	44.9±46.7	135	56.3±46.3
144	89.0±26.1	60.2±47.6	91	51.2±25.6
157	98.4±26.2	46.9±46.7	168	34.7±50.9
188	99.6± 1.0	60.2±45.3	132	46.3±38.3
179	92.7±10.9	47.4±52.2	160	44.4±34.2

Effects of seed size on preference in quelea

The literature indicates that physical characteristics of the sorghum seed will influence acceptance by quelea. Small seeds are reportedly more readily accepted than larger ones. However, the differences in acceptance may be influenced by the stage of maturity. We compared large and small seed varieties at four stages of development to determine if, in fact, seed size is a significant factor in food preferences of quelea.

The results (Table 17) indicate that size has little influence on quelea preference of sorghum seeds during the milk or dough stages. However, there is a strong preference for the small seed in mature grain. The NK-1467 seed grew to a larger size in the greenhouse than it normally does in the field. Consequently, the size difference between the two varieties was not as wide as anticipated. The possibility that a large, early-maturing seed may alleviate quelea damage in some situations is worthy of further investigation.

Table 17. Percent acceptance by quelea of large and small sorghum seeds at different stages of development. (All compared to mature NK-1467 variety.)

Variety	Milk stage	Light-dough stage	Firm-dough stage	Mature
NK-1467 (small)	65.9	83.5	49.5	N/A
NK-C21319 (large)	59.0	75.0	49.8	12.3

Concentration of polyphenolics in bird-resistant sorghum seeds at various stages of development

Tannins in bird-resistant sorghums are reportedly high in the milk and dough stages of development and essentially absent after full maturation. However, in our analysis of total polyphenolics we found that all tannins do not disappear after maturation. A better understanding of these compounds would contribute much to the development and application of bird control methodology based on natural repellent properties. Therefore, a cooperative study was initiated with Dr. J. O. York of the University of Arkansas to investigate the polyphenolic content of eight sorghum varieties at four stages of development.

The results are summarized in Table 18. These data indicate that a number of reactive phenolics are produced during the milk stage, continue to increase in the dough stages, and decrease during ripening. However, this does not necessarily mean that they decompose. There is good evidence that they polymerize to a degree that many phenolic groups are no longer active. Thus, the astringent (i.e. repellent) properties decrease but the tannin content still present is undesirable from a nutritional standpoint. The ultimate objective of this

and related studies is to find a bird-resistant property that is effective during the immature stages but will not be deleterious nutritionally when the grain is fully mature.

Table 18. Polyphenolic content of sorghums in various stages of development (Catechin equivalents).

Variety	Milk stage	Light-dough stage	Firm-dough stage	Mature
Hegari	1.60	1.84	1.58	1.35
BR-54	1.80	3.55	5.13	3.61
AR-3005	2.44	3.93	3.88	3.38
IS-2801c	1.83	2.93	3.90	2.41
IS-2266c	3.16	4.65	2.23	1.71
G-516	2.24	4.57	5.17	3.36
IS-2403c	2.20	2.38	4.05	3.06
TAM-2566	2.03	2.58	3.33	2.65

Chemical protection of growing crops from rodent damage: a feasibility study

Traditional methods for protection of agricultural crops from rodent damage generally involve baiting. Poor acceptance, bait shyness, and genetic resistance are among the types of problems inherent to baiting. This study was designed to investigate the feasibility of repellents (topical or systemic) as alternate means of agricultural rodent control. Since this approach would involve application of a chemical directly on a food crop, registration requirements would be an important practical and economic consideration. Hence, candidate chemicals were selected from a list of 30 products already registered for use against other cereal grain pests. Twelve representative chemicals were chosen and initially tested by bioassay procedures on wheat seeds (Table 19).

Table 19. Percent reductions of rat intake of 0.3% chemically treated wheat seeds.

Chemical	Percent reduction of treated seed intake
Furadan	64.8
Methiocarb	76.0
Dimethoate	62.0
Guthion	70.0
Orthene	32.0
Diazinon	10.8
Mobam	70.6
Di-Syston	69.6
Accothion	9.6
Thimet	74.0
Metasystox	7.6
Demeton	73.6

Eight compounds successfully protected the wheat seeds (>60 percent drop in consumption). Four of these were organophosphates with similar structures and activity and could essentially be represented by one compound--Di-Syston. Therefore, Di-Syston, Furadan, methiocarb, dimethoate, and Guthion were chosen for testing as a topical application on growing plants. These tests failed to reveal any repellent effects for any of the chemicals on rice plants.

Admittedly, compounds probably exist that would be better candidates than those used in these tests. However, five compounds of differing chemical nature which protected wheat seeds from consumption did not affect damage to growing plants regardless of concentration. If these unrealistic topical applications will not protect plants, we

find it difficult to believe that any systemic will work. These results tend to indicate that the feasibility of this concept is questionable.

Diphacinone range-finding toxicology study--rats

Examination of published data on the toxicity of diphacinone reveals considerable variation in the acute oral LD_{50} value for rats. One report gave a 14-day subacute LD_{50} value in rats to be >0.1 mg/kg per day (oral). However, no satisfactory information on the chronic toxicity of diphacinone, nor definitive subacute toxicity studies to determine a "no-effect" level have been reported. Such information would add to the body of knowledge of this compound as a rodenticide and would be valuable baseline information for purposes of pursuing regulatory agency (e.g. FDA or EPA) registration for other uses as, for example, a systemic drug for control of vampire bat parasitism on cattle. A 90-day chronic toxicity study and a subsequent 21-day study aimed at determining the approximate "no-effect" chronic dose level for diphacinone were completed. Elars Bioresearch Laboratories of Fort Collins, Colorado, provided consultive and pathological evaluation services on a contract basis.

Ninety-six animals were tested on six diphacinone concentrations (0.5, 0.25, 0.125, 0.0625, 0.0313, and 0 ppm) in the 90-day study. No abnormalities were evident in 24 animals sacrificed at 30 and 60 days. Prothrombin times were within the normal range. Gross necropsy, hematology, and clinical chemistry determinations were carried out on the remaining 72 animals. Hematology and clinical chemistry values were comparable for animals of all groups, however, fibrinogen values for high-level animals (0.5 ppm) were somewhat lower. Prothrombin times were normal. Two animals died and both exhibited subdural hemorrhage as cause of death, with hair loss and bleeding around the eyes. Several animals in different groups exhibited bleeding around the eyes but it was not dose-related. Gross necropsy findings were so few and scattered that histopathological examination of tissues was considered unnecessary. In conclusion, the animals generally appeared healthy and in good condition irrespective of dosage regimen, with the exception of the two that died with indications of subdural hemorrhage. Gross necropsy findings were sparse and as one would expect in normal laboratory rats. There was apparently no drug- or dose-related response in this test.

The results of the 90-day test led to the subsequent 21-day test in which higher diphacinone concentrations (4, 2, 1, 0.5, 0.25, 0.125, and 0 ppm) were used. All animals in the 4-ppm and 2-ppm dose-level groups succumbed to diphacinone poisoning. Postmortem examinations revealed massive internal hemorrhage, primarily in the thoracic or

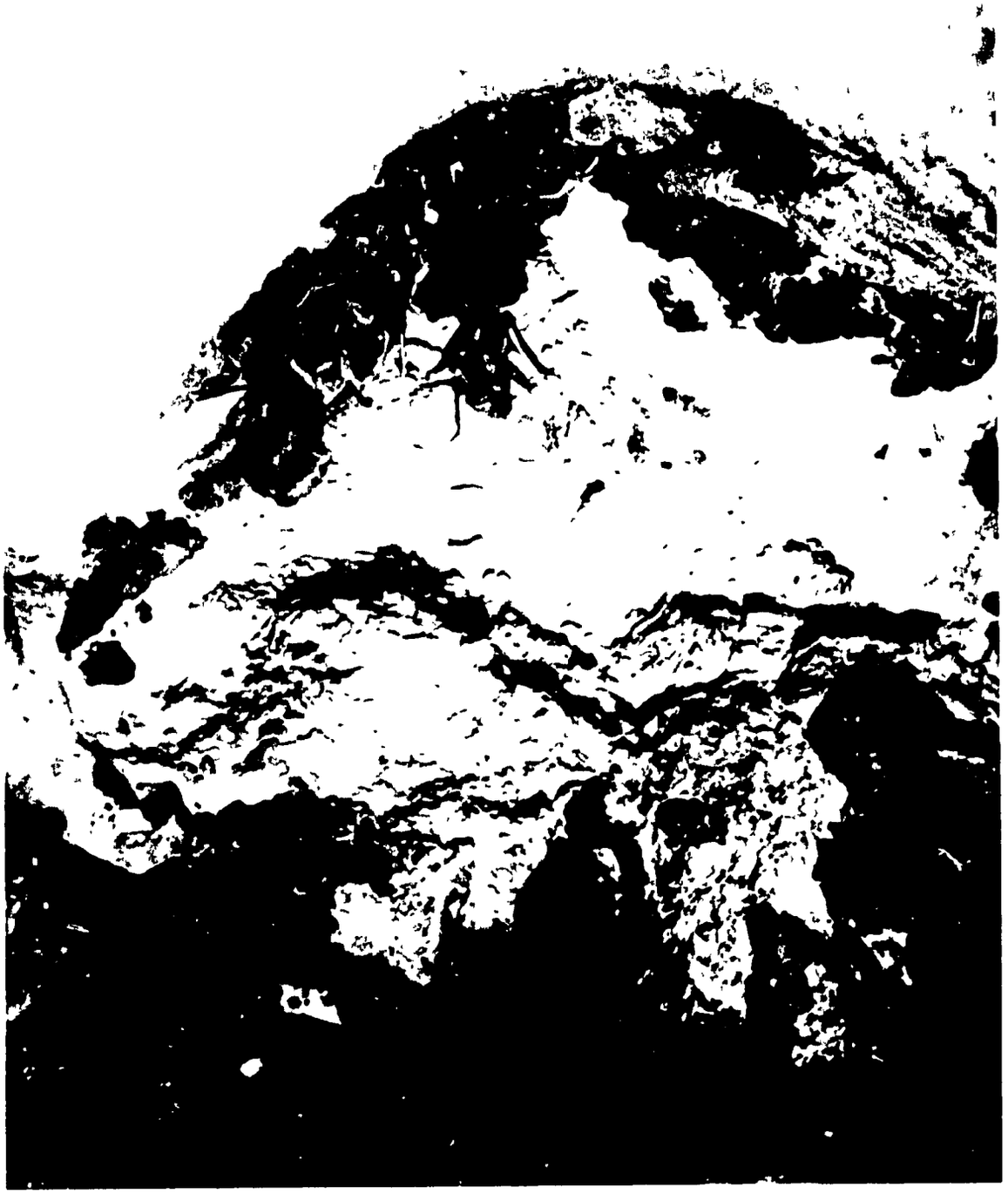
abdominal area. The remaining animals showed no clinical symptoms of intoxication during the test period. The eye discharge, noted in several animals in the earlier 90-day test, did not manifest itself during this trial. No abnormalities were noted during gross pathological examination with the exception of one rat at the 0.5-ppm level which had some hemorrhage in the thymus. Again, prothrombin measurements were normal.

It appears that a very sharp break in toxicity exists between 2-ppm and 1-ppm concentrations of diphacinone when fed to rats in bait form. These studies demonstrate that there is "no effect" of importance from chronic feeding below the 1-ppm level.

Chemical reduction of diphacinone residues in the tissues of rats

This was a preliminary study to investigate the feasibility of reducing anticoagulant residues in animal tissues by chemical means. Three general approaches involving six different chemicals (single oral doses) were evaluated. The three approaches and the chemicals utilized were: (1) displacement of the anticoagulant from plasma protein binding (phenylbutazone); (2) competition with anticoagulants at the site of action where they interfere with hepatic synthesis of clotting factors (Vitamin K); and (3) induction of microsomal enzyme action resulting in increased metabolism of anticoagulant residues (phenobarbital, coumophos, DDT, and methoxychlor).

A review of the literature reveals that the concept of chemical reduction of drug or pesticide residues is valid and has been successfully accomplished. However, we were unsuccessful in this attempt. Statistical analysis of the results showed no significant differences between treated and control animals. However, there were significant differences ($p < .001$) between male and female residue levels in both liver and kidney tissues. This is to be expected since males have more active metabolizing enzyme systems than females. The occurrence of this effect offers encouragement as to the feasibility of the procedure since it is now assumed that metabolism of diphacinone residues is dependent on liver microsomal enzymes which are subject to induction and concomitant increased metabolism. In addition, there were some significant differences among some treatment groups. Residues in liver samples from the methoxychlor- and coumaphos-treated groups were significantly different from the phenobarbital- and phenylbutazone-treated groups. Though these treatment differences in the liver are not great, the fact that there is a treatment effect offers hope that more vigorous stimulation of the metabolic process may produce the desired reduction of diphacinone residues. Further research in this area is being considered.



Vampire bats roost together in groups, separate from other bat species, in caves. Because of this behavior, only vampires are susceptible to topical control treatments using the drug diphenadione.

ASSOCIATED RESEARCH ACTIVITIES

Scientists in several countries have cooperated with the DWRC and conducted research projects in support of, or pertinent to the activities of the AID/DWRC Vertebrate Pest Control Program. The efforts of these individuals and their contributions to the body of knowledge in the area of vertebrate pest control is appreciated. Summaries of their work are presented below.

Investigator: Rogerio Serrao Piccinini
Country: Brazil
Title: The use of diphenadione (2-diphenylacetyl-1,3-indandione) for vampire bat control in endemic rabies areas, northeastern Brazil.[1]

Vampire bat control using diphenadione (2-diphenylacetyl-1,3-indandione, an anticoagulant) was applied in endemic rabies areas (Pernambuco and Algoas States) in northeastern Brazil. Analyses of field data showed that the estimated number of vampire bats living in the area was reduced by 99.4 percent 2 years after the control had been applied. The best single method was the systemic treatment of cattle, but its combination with topical treatment of vampire bats was better than the first alone. A statistically significant decrease in the number of rabies cases in livestock was observed in the 2 years following control. A regression model to predict the number of vampire bats that will be caught on a given farm is described as a tool for control methods. Also, an optional method of topically treating fresh bites on suckling calves and cows in their late gestational period was used with good results. Recommendations are made to establish a Federal Pest Control Research Center in Brazil to study and solve economic problems in the agriculture and animal sectors, such as vampire bat predation and disease transmission.

[1] A thesis submitted to the University of California, Davis, in partial fulfillment of requirements for the degree of Master of Preventive Veterinary Medicine.

Investigator: Edgar Orlando Ortiz Aldana
Country: Guatemala
Title: Evaluacion de la aplicación topica de la difenadiona como método de control para el murcielago hematófago en 6 regiones del pais [Evaluation of the topical application of diphenadione as a method of control for the hematophagous bat in six regions of the country].[2]

In the trials carried out in six different regions of the country, nylon nets were stretched next to corralled cattle during the night and captured vampires treated (one for each five fresh bites) and later released. As a general average, in the six trials carried out, there was a reduction of bites of more than 93 percent 20 days after treatment.

A total of 90 vampires were treated by the topical method which consists of applying approximately 1.5 cc of diphenadione on the dorsal surface of the bat.

Based on the results obtained, the treatment is considered very good and applicable in our medium to attain almost absolute control. With the method employed here, a team of properly trained operators can move into a determined zone and reduce the population of vampires more rapidly than with an extensive program of diphenadione injections by the intraruminal method.

Laboratory rabies diagnosis was performed in the Animal Health Laboratory on 10 percent of the captured vampires. The results were negative to the Seller and fluorescent antibody methods. For this reason, it is presumed that the prevalence of rabies is relatively low in the vampire population of the country.

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[2] A thesis submitted to the University of San Carlos of Guatemala in partial fulfillment of requirements for the title of Medico Veterinario y Zootecnista.

Investigator: Carlos Calvi
Country: Uruguay
Title: Ensayo de interrupción del ciclo reproductivo de la "paloma mediana" *Zenaida auriculata* [An attempt to interrupt the reproductive cycle of the "medium dove" *Zenaida auriculata*].

The objective of this study was to determine if driving doves off their nests during the incubation period would result in the deaths of the embryos. The test was carried out in three nesting areas, one of which served as a control. Carbide exploders were used to frighten the birds. Several preliminary conclusions were reached.

1. It was verified that by use of carbide exploders in a small area, it is possible to drive a large percentage of nesting doves off their nests for a period of at least 3 h.

2. The most opportune moment to initiate the explosions is before total darkness.

3. With ambient temperatures of 18° and 20° C during the nights of the experiments, the embryos most sensitive were those at the mid-stage of development.

4. The doves continued to incubate eggs with dead embryos for at least 4 days.

5. In Test #2, a high percentage (43 percent) of nests were abandoned.

6. It would be practical to repeat the experiment and examine the following points:

a. Daily repetition of the explosions for 14 days, and in this manner affect a larger percentage of embryos when they are at the mid-stage of development.

b. Determination of the maximum area that can be covered with two or three cannons.

RESEARCH UTILIZATION

Annual bovine losses resulting from vampire bat-transmitted rabies are estimated at approximately 1,000,000 head in Latin America. Daily loss of blood, mortality of other livestock, and secondary infections further aggravate the problem.

The original objective of research under this project was to develop techniques for controlling vampire bats. The project began in June 1968, funded by the Agency for International Development (AID) and the Mexican Government under a Participating Agency Service Agreement with the U.S. Fish and Wildlife Service (FWS), and the Instituto Nacional de Investigaciones Pecuarias (INIP). Laboratory and field investigations were conducted at the FWS Vampire Bat Research Station in Mexico City, Mexico. The station officially closed in December 1973, after species-specific control methods were developed.

AID has continued to fund this program with the objective that Denver Center biologists would help Latin American countries develop and initiate control campaigns through training and technical assistance. This funding ends in September 1978 when the Denver Center will cease to be directly involved in vampire bat control training programs.

Vampire bats range from tropical Mexico to northern Chile and northern Argentina. When our cooperative extension program began, there was one regional vampire bat control program in Mexico. There are now viable, country-funded control programs in eleven of the nineteen countries which suffer vampire bat predation.

The two methods for reducing vampire bat populations which were developed by this project are described in detail in the 1971 and 1972 Annual Reports and in several scientific journals.

In the topical method, vampire bats are captured with mist nets set around corralled cattle or at cave entrances. Approximately 1.5 cc of a petroleum jelly-diphenadione mixture is placed on the dorsal surface of each captured bat; the bats are then released to return to their roost. Because vampire bats roost in compact groups, they physically pass the chemically treated jelly from one to another. The bats in the problem colony die after ingesting the chemical during grooming.

In the systemic method, cattle are injected (intraruminal) with 1.0 mg of diphenadione per kilogram of body weight. The drug is absorbed

and circulates in the blood. Any vampire bat that feeds from a properly treated animal, within 72 h after treatment, receives a lethal dose of the drug. Treating all the cattle in a herd gives 90-95 percent reduction in fresh biting.

Following are observations of vampire bat control programs in countries visited by DWRC personnel in 1977.

Bolivia

Dr. Jorge Saucedo B. of the Committee for the Development of Chuquisaca began a study in 1976 to evaluate the two control methods in an area heavily populated with wildlife. Theoretically, vampires could feed on wildlife and, thus, reduce the effectiveness of the systemic method which is only effective for 72 h.

The experiment was conducted in a narrow, 75-mile-long valley between the Parapeti and the Pilcomayo rivers. Three 12.5-mile-long zones within the valley were defined (see 1976 DWRC Annual Report for details). In one zone, the topical control method was applied. The second zone served as the control and in Zone 3 only cattle were treated. Evaluations were planned at 1-, 6-, and 12-month intervals after treatment.

Dr. Saucedo reported 6 months after treatment that the systemic control method appeared to be the most effective. He based this upon ease of application and cooperation received from cattlemen. Complete data from this study will be reported in 1978.

Brazil

Dr. Rogerio Piccinini has recently begun a study on vampire bat control in the state of Minas Gerais. The objective of this 3-year study is to determine what combinations of bat control and/or vaccination programs are most effective in controlling rabies.

Dr. Piccinini plans to divide the 54,000 ranches in the study area into three zones. In Zone 1, cattle will be vaccinated only; in Zone 2, vampire bats will be controlled; and in Zone 3, vaccination and bat control will both be used. He hopes to learn which approach is most effective and economical for Brazil.

Colombia

At the invitation of the Instituto Colombiano Agropecuario (ICA), three DWRC staff members participated in a training seminar on paralytic rabies control in Santa Marta, Colombia, from January 31 to February 5, 1977.

The training seminar was organized and sponsored by the Division of Animal Health (ICA). A total of 74 persons, including government and private veterinarians, cattlemen, and other interested parties participated in the program.

The conference came about partially as a result of an outbreak of paralytic rabies in the Sierra Nevada de Santa Marta mountain range. In addition to formal presentations, the participants had field demonstrations on the use of mist nets for capturing vampire bats, identification of bats, the topical control technique, examination of cattle for evidence of vampire parasitism and the systemic control technique. On one ranch used in the field demonstrations, the participants encountered a dying calf which exhibited clinical symptoms of paralytic rabies.

Vampire bat control distribution centers.--The Ministry of Agriculture has established vampire bat control distribution centers in all nine ICA regions throughout the country. The objective is to have the materials available locally when control needs to be applied.

Funds have been allocated for control programs in regions suffering rabies losses. Presently, regional control programs are being conducted in the states of Cesar, Guajira, and Sucre.

Nicaragua

Nicaragua has completed the fourth year of their vampire bat control program (Table 20). In 1978, the control program will be turned over to cattlemen's associations. Ministry of Agriculture veterinarians will train the associations' veterinarians in the systemic control method (treating cattle). The Ministry will not release the topical method, but their veterinarians will be available to apply this method when the systemic control method is not applicable or if there is a rabies outbreak.

Table 20. Results of the 4-year vampire bat control program.

Year	Ranches visited	Cattle examined	Fresh bites	Vampires treated	Cattle treated	Reduction in fresh bites (%)
1974	724	58,980	46,452	908	31,577	90
1975	909	112,355	50,070	622	73,088	92
1976	367	75,632	20,784	850	32,343	87
1977	124	22,858	6,070	316	11,134	91
	2,124	270,825	123,376	2,696	148,142	90

Panama

Panama has elevated its vampire bat control program to a national level. Eight veterinarians stationed throughout the country are working on vampire control.

The coastal area of the Department (state) of Los Santos suffered a severe drought in late 1976 and early 1977. Lack of adequate pasture forced the livestock owners to move their cattle inland to a more mountainous region. As a result of this move, the resident vampire population did not have sufficient livestock to prey upon and began preying on humans. A total of 95 people were bitten by vampire bats in December 1976 and January 1977.

Personnel from the National Vampire Bat Control Program visited the affected area in February to evaluate the problem. They found vampires living in abandoned wells. Bats were trapped at four wells and treated with diphenadione. After the control measures were applied, all human predation ceased.

Paraguay

Preliminary arrangements for a vampire bat control training program were made by a DWRC staff member in October. The training is scheduled for early 1978 and will be presented by Drs. G. Clay Mitchell, DWRC, and Enrique Sanchez, Ministry of Agriculture/Nicaragua. This training was requested to prepare Ministry personnel for the national vampire bat control program.

The Ministry of Agriculture has submitted a proposal to the Inter-american Development Bank for a livestock loan. Included in the proposal is a request for funding to cover the three most costly diseases to the livestock industry: foot-and-mouth disease, brucellosis, and rabies.

Socio-economic evaluation of vampire bat control in Latin America

In January 1978, Dr. Daniel D. Badger, Resource Economist, Oklahoma State University, will begin a socio-economic evaluation of vampire bat control in Latin America under a special contract with AID.

The objectives of this study are:

1. Obtain secondary data and analyze the costs of AID-sponsored research and development of the vampire bat control program.

2. Obtain data from governmental agencies of several countries and analyze these costs to determine the costs of implementing the control programs.

3. Evaluate the economic benefits, both to the agricultural sector and to related sectors of the economy, and determine the distribution of these benefits among different groups of people in society.

4. Describe and quantify, if possible, the quality of life effects, as well as related social and environmental quality effects of the vampire bat control program.

5. Determine if there have been any beneficial effects on livestock producers in rural areas who have not participated directly in the program.

6. Derive a cost:benefit ratio of the control program to date, and project the likely benefits and costs if the program is implemented more intensively in some or all of the countries.

The primary cost:benefit analysis will be conducted in Nicaragua. A random sample of livestock producers will be selected in Nicaragua and survey forms will be developed and used to obtain basic data for analysis through personal interviews with the producers.

Two research associates at OSU will be hired to collect these data. One associate will interview farmers and the other will interview city dwellers, doctors, and city officials. Approximately 6 months will be required to complete the interviewing in Nicaragua.

In addition tc Nicaragua, trips a planned to Trinidad, Venezuela, Colombia, Panama, Brazil, Honduras, and Mexico. Basic cost:benefit data will be collected in each country. Results of this study will be reported as soon as they are available.

PARTICIPATION IN MEETINGS, CONFERENCES, SEMINARS

Benigno, E. A. "Philippines: methods of assessing small mammal pest populations." Paper presented at BIOTROP Symposium - Small Mammals: Problems and Control. Los Baños, Philippines. Nov. 30-Dec. 22, 1977.

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Bohl, W. H. Attended IXth Coordinating Committee Meeting of the FAO UNDD/SF Regional Project, Research into the control of grain-eating birds (Quelea quelea). Rome, Italy. Dec. 5-9, 1977.

Bullard, R. W. "Efficacy and safety of the systemic method of vampire bat control." Paper presented at Vampire Bat Control Seminar. Santa Marta, Colombia. Jan. 30-Feb. 5, 1977.

_____. Chaired session on "Flavor chemistry of animal foods" at 174th American Chemical Society Meeting. Chicago, Illinois. Aug. 28-Sep. 2, 1977.

De Grazio, J. W., and S. A. Shumake. "Controlling quelea damage to small grains in Africa with methiocarb." Paper presented at UNITAR--State of California Conference on Alternative Strategies for Desert Development and Management. Sacramento, California. May 31-Jun. 7, 1977.

Elias, D. J. "Efectos del anticoagulante difenadiona en terneros lactantes." Paper presented at Vampire Bat Control Seminar. Santa Marta, Colombia. Jan. 30-Feb. 5, 1977.

Estioko, B. R. "Philippines: rat damage and control in Philippine sugar cropping." Paper presented at BIOTROP Symposium - Small Mammals: Problems and Control. Los Baños, Philippines. Nov. 30-Dec. 22, 1977.

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Reidinger, R. F., Jr. "Ecology of rodent control." Seminar presented at Region III Regional Crop Protection Center. Maligaya, Philippines. Dec. 9. 1977.

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Sanchez, F. F., and R. F. Reidinger, Jr. "The sustained baiting method: its description, rationale, development, and evaluation in Philippine ricefields." Paper presented at BIOTROP Symposium - Small Mammals: Problems and Control. Los Baños, Philippines. Nov. 30-Dec. 22, 1977.

Savarie, P. J. "Problems and recent advances in the development of rodenticides." Paper presented at BIOTROP Symposium - Small Mammals: Problems and Control. Los Baños, Philippines. Nov. 30-Dec. 22, 1977.

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_____. "Laboratory safety problems." Seminar presented at the Rodent Research Center. Los Baños, Philippines. Dec. 19, 1977.

Shumake, S. A. "A review of food preference behavior in birds and mammals." Paper presented at 174th American Chemical Society Meeting. Chicago, Illinois. Aug. 28-Sep. 2, 1977.

Sumangil, J. P. "Philippines: national rat control program in the Philippines." Paper presented at BIOTROP Symposium - Small Mammals: Problems and Control. Los Baños, Philippines. Nov. 30-Dec. 22, 1977.

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SUMMARY OF ACCOMPLISHMENTS

Program

1. Personnel from the Center assisted AID/W and USAID Missions in preparation of project documents for work in Bangladesh, Philippines, and Latin America, and participated in a Research Advisory Committee review of project activities. Research activities on bird control in East Africa were transferred from Arusha, Tanzania, to Khartoum, Sudan, where a new working agreement was negotiated between USAID/Khartoum and the Sudan Ministry of Agriculture, Food, and Natural Resources. Preliminary arrangements were made for a joint FAO, West German (GTZ), U.S. (AID/W) project formulation mission to visit five East African countries to develop means to coordinate bird control research activities carried on by national and international organizations.

2. Project personnel spent 439 man-days in 18 countries at the request of USAID Missions, foreign governments, or international organizations. Activities included specific research studies, assisting field personnel in ongoing research, project review, supervision and program development, attendance at international meetings, and liaison with research organizations.

Training and communication

3. Fourteen staff members and cooperators participated in seven professional meetings, presented 18 professional papers or seminars, and chaired six meeting sessions. Sixteen staff members and cooperators authored 11 professional publications during 1977.

4. Denver-based staff reviewed programs and discussed research progress with numerous visitors and responded to requests for technical information on vertebrate pest control from many countries. Research trainees (one from Venezuela; two from the Philippines) spent several weeks at the Center reviewing literature and learning research techniques. Three staff members participated in a 6-day training seminar on vampire bat control held in Santa Marta, Colombia. Plans were made for a similar workshop to be held in Paraguay in early 1978.

5. Center biologists continued to assist Latin American countries in training control personnel and in developing programs for reduction of vampire bat depredation. Observations in Bolivia, Brazil, Colombia, Nicaragua, Panama, and Paraguay indicated considerable progress in organizing programs, although projects are in

varying stages of development. Assessment work in Nicaragua, where the national bat control campaign is in its fourth year, indicated that fresh cattle bites are still being reduced by more than 90 percent by control treatments. Plans were made for a detailed study of economic benefits to be conducted under a university contract.

6. Two staff members of the Plant Protection Department of Sudan were accepted as USAID participant trainees and will undertake graduate training programs at Bowling Green State University, Ohio.

7. Training and communication activities in the Philippines included presentation of lectures, workshops, or demonstrations to over 3,000 extension personnel and key farmers and briefing more than 300 visitors on the Rodent Research Center (RRC) program. Numerous international requests for information on rodent control were also handled by the RRC. Four agricultural technicians from Thailand and five from Bangladesh participated in brief training programs at the RRC; two RRC staff members made U.S. study tours as USAID participants in conjunction with their graduate programs. One staff member and three students participated in the Second Regional Training Seminar on Field Rat Control and Research sponsored by the Bureau of Plant Industry and the Philippine-German Crop Protection Program. Other staff members taught or helped teach classes in Vertebrate Pests and Crop Protection at the University of the Philippines at Los Baños. In the cooperative graduate program, one M.S. was completed; three Ph.D.'s and six M.S. programs are in progress.

Research

8. In Sudan, considerable efforts have been placed on large-scale quelea control over the past 30 years; much biological research and some control methods evaluation were carried out by FAO and Sudanese scientists. With the initiation of work in Sudan, project personnel reviewed and summarized this information and have assisted in preparation of tables of crop phenology and summary maps of major bird problem areas in Sudan.

9. In Kassala Province, Sudan, field cages were used to study quelea damage to grain sorghum in fields. Quelea were found to have the capability of destroying about 38 g of sorghum daily; at current price levels, each quelea is capable of destroying approximately 43¢ U.S. of sorghum during the approximately 30-day nesting period. Our Sudanese counterparts, through food habits studies at a nesting colony have determined that 80 percent of the diet of quelea consist of sorghum during this limited period when it is susceptible to damage. A colony of 1 million breeding quelea has the capability of destroying more than 400 ha of sorghum.

10. In the same area, a preliminary field test of methiocarb with an aerial application of 4 kg/ha did not reduce quelea damage to sorghum plots. The same concentration applied from the ground with knapsack sprayer resulted in good protection. Small-scale ground application of repellents will be evaluated for potential application in some sorghum-growing areas of Sudan.

11. The Rodent Research Center program in the Philippines was incorporated as a part of the new Philippine National Crop Protection Center. This organization, along with seven affiliated Regional Crop Protection Centers, has primary responsibility for research, development, and dissemination of integrated crop protection systems for the country. Development of the regional centers will provide a means for carrying on detailed research and evaluation studies of rodent and bird control methods in many diverse crop areas throughout the Philippines.

12. Fieldwork was completed on a long-term study of crown baiting with anticoagulant rodenticides to protect coconut palms from rat damage. Coconut production in treated plots averaged about 2.8 times the pretreatment level. At current prices, the estimated cost:benefit ratio for this method was 1:28. Based on nearly 3 years of evaluation, this method of monthly treatment of 25 percent of the palm crowns with packets of warfarin bait clearly provides long-term reduction of rat damage with excellent economic return. A parallel study has been initiated to evaluate locally prepared wax blocks as a means of simplifying palm crown treatment.

13. A study of the behavior of Rattus r. mindanensis and Rattus exulans in coconut areas is underway. In cage trials, mindanensis damaged nuts much more readily than exulans and preferred the button-size nuts. In field areas, approximately 77 percent of the fallen nuts showed obvious signs of rat damage. Trap success for mindanensis in coconut groves was 18.6 percent at ground level and 0.8 percent in tree crowns; for exulans, comparable trap success was 10.5 percent and 0.2 percent, respectively.

14. Fields have been selected for studies of the extent and distribution of rat damage to growing corn. Preparation of distribution maps of rat damage in the fields is underway and will be used to construct models for simulating potential damage assessment approaches.

15. A wax-bait formulation was evaluated for use in sustained baiting programs in ricefields. Compared with a standard rice/warfarin bait, consumption of the wax formulation was nearly five times greater and feeding occurred over a longer period. Preharvest damage surveys indicated reduced damage on plots receiving both wax bait and standard bait in treatments, but additional studies, including those on economic benefit, are required.

16. A study was completed on baiting in uncultivated marsh habitat adjacent to ricefields to reduce rat damage to rice. Baiting was carried out during the period from transplant to harvest of the adjacent rice crops on transects 25 and 50 m from the marshland-crop interface. In fields adjacent to the baited area, the proportion of tillers cut by rats averaged 2 percent in preharvest surveys, and the farm yields averaged about 3 metric tons/ha; in a reference area about 1 km away, cut tillers averaged 19.4 percent and yields averaged about 2.4 metric tons/ha. Bait consumption on 40 floating platforms located at 50-m intervals along the two 1-km transects averaged 53 kg per month during the crop season.

17. Surveys were conducted in Laguna Province, Philippines, to determine the awareness and degree of adoption of rat control methods by farmers participating in the national rice production loan program. One year after availability of the rodent control portion of the loan program, use of sustained baiting with chronic toxicants by farmers had increased from 2 percent to 12.5 percent. None of the farmers using chronic toxicants were following all procedures outlined in the extension recommendations provided with the loan. Of 320 eligible farmers surveyed, only 60 had actually used the agricultural loan for production inputs. Of these, 67 percent used chronic toxicants for rodent control; rat damage was lower in the fields of farmers using chronic toxicants than in fields where farmers used other methods.

18. Several studies were carried out in the Philippines to evaluate toxicants and related application methods. Five local formulations of chronic rodenticides were compared to determine relationships among cost of materials, bait consumption, death times, and weights of test animals. Cost per mortality was significantly lower for three derivatives of coumarin than for two indandione compounds. Work was initiated on development of a system to monitor long-term changes in the toxicity of chronic rodenticides in Philippine rat populations. Preliminary work was also undertaken to evaluate the potential of grease formulations of toxicants for field rat control; a device was constructed for evaluation of tube stations as a potential means of delivering baits or greases and for assessing rodent activity.

19. Surveys to assess rat damage to sugarcane on small farms on Negros Islands, Philippines, were carried out in 18 locations in fields ranging from 1 to 7 ha. Of the stalks surveyed in the fields, 7.2 percent had obvious rat damage. Sugar content averaged 19.2 percent for healthy stalks and 17.2 percent for damaged stalks.

20. A preliminary field trial of a topical repellent to reduce rice damage by Philippine weavers (Lonchura spp.) was conducted. A

small ricefield receiving heavy damage was treated with methiocarb (1.7 kg a.i./ha) when rice heads were at the milky-dough stage. Observations of birds and damage patterns were made on the treated plot and surrounding fields and in a similar reference area about 1.5 km away. Damage continued on both treated and reference areas after spraying; however, the rate of increase was significantly higher in the untreated fields. Feeding activity by birds in the treated area appeared to shift to surrounding untreated fields.

21. Another small-scale trial was conducted using locally made bird glue placed on perches at 40 locations in and around a 0.2-ha ricefield. Bird activity was observed for 2 days before treatment and 2 days after; 40 birds were caught on perches during the first day after treatment. Activity in the field decreased 97 percent the first day; no birds were observed on the second day after treatment. Distress calls by entangled birds probably accounted for these results and additional evaluations of this approach are planned.

22. A 1-year study of the food habits of bats foraging in the area of ricefields was completed in the Philippines. The principal species studied, Scotophilus temmincki, feeds on many species of pest insects including leafhoppers, planthoppers, crickets, grasshoppers, and moths. Some beneficial insects were also taken as food.

23. Work was begun at the Denver Center to evaluate commercial rodenticide formulations available in developing countries and selected candidate formulations on several species of rodents of economic importance in developing agriculture. Such tests will be conducted on a continuing basis as commercial chemicals and foreign rodent species become available. More detailed toxicological investigations and follow-on field trials will be conducted with selected chemicals.

24. An investigation was completed of variables affecting ultrasound repellency in R. r. mindanensis using four commercial ultrasound generators with frequencies of 20 kHz, 20-30 kHz (variable), 40 kHz, and 15-25 kHz (variable). Under test conditions, food consumption and activity of mindanensis in the sound chamber were suppressed using the 20-kHz device, but no parallel reduction in these measures was observed in similar tests with R. norvegicus. Some reduction of food consumption and activity of mindanensis was also observed with the 15- to 25-kHz variable frequency device. When sound intensities were adjusted to simulate operationally realistic levels, neither species responded to these frequencies. Although many commercial ultrasound devices have been marketed for rat control, their efficacy has not been adequately assessed under operational conditions.

25. Six chemicals were evaluated as candidate repellents for reducing damage to young corn by cotton rats (Sigmodon hispidus). Di-Syston and Furadan produced greater than 90 percent repellency in wheat seed bioassay tests, but neither chemical reduced rat damage to growing corn plants when applied in topical or soil treatment tests. Semifield tests using Di-Syston and the aversive drug lithium chloride in combination with saccharin and glucose suggested that the addition of taste cues might improve the action of potential repellents.

26. Current results of work on a continuing project to study the response of rats to rice aromas tended to support the hypothesis that taste experience is necessary for rats to exhibit attraction to odors. Food consumption and feeding times were more sensitive measures of the odor-attractant quality of bait stations or materials than were measures of activity or visits. These factors must be taken into account in designing field tests of odor-enhanced bait materials.

27. A test system was developed to study rat feeding patterns by automatically recording food consumption at 1-min intervals over periods of several days. Initial trials with ground rice containing warfarin, zinc phosphide, or cellulose indicated that R. r. mindanensis readily detected toxic chemical additives and modified their feeding patterns to intermittent, brief sampling of food material from the longer meal periods observed with the cellulose control.

28. An analytical method was devised to determine warfarin residues in water, soil, and plant material. Residues in soil and plants could be detected to 0.1 ppm and those in water to 0.01 ppm. Recoveries from fortified samples averaged from 70 percent for plant samples to 104 percent for soil samples. This method and a similar procedure for diphacinone will be used to complete work on a crop residue study in the Philippines.

29. Thirty agricultural chemicals registered for various pest control uses on cereal grains were considered as candidate rodent repellents for systemic or topical use on growing rice plants. Of 12 chemicals tested by wheat-seed bioassay on R. r. mindanensis, 8 showed repellent activity greater than 60 percent. Five of these compounds, with dissimilar chemical structures, were tested by topical application to rice plants exposed to groups of rats in enclosures. No repellent effects were observed in these tests, and it was concluded that the concept has limited feasibility.

30. Two range-finding studies were completed to determine the "no-effect" level of diphacinone consumed in food by laboratory rats. This material is widely used in animal control as a rodenticide and

also, in the drug form (diphenadione), as a livestock systemic vampiricide. A sharp break in rat toxicity was observed between 2- and 1-ppm concentrations in food, suggesting that there is no chronic effect in rats orally dosed below the 1-ppm level.

31. A feasibility study was completed of three potential methods of chemically reducing residues in tissues of rats fed sublethal amounts of diphacinone. No differences were observed between control and treated animals in tests based on displacement of the anticoagulant bound to plasma protein, competition with the anticoagulant at the site of action, or induction of hepatic microsomal enzymes. Significant sex differences observed among treated animals offered some encouragement for further investigation.

32. A preliminary investigation of the feeding behavior of quelea indicated that naive birds could learn to imitate the feeding patterns of birds conditioned to avoid colored food by treatment with the repellent chemical methiocarb. These data suggest that altering the feeding behavior of some birds in a depredating flock through repellent treatments might provide a means to influence behavior of the entire flock without direct chemical contact with all individual birds.

33. A significant negative correlation was established between polyphenol content and the relative preference of quelea for pelleted sorghum varieties described as "bird-resistant." Bird-resistant varieties were accepted more readily under darkened conditions than under artificial lighting, suggesting that color differences between treatment and control pellets influenced the taste preference response of birds. Subsequent tests confirmed the inability of quelea to maintain color-conditioned responses under darkened conditions. In comparative tests, quelea were found more responsive to the repellent effect of bird-resistant sorghums than red-winged blackbirds.

34. Quelea were found to show little size preference for sorghum seeds during milk or dough stages. However, there was strong preference for small seed in mature grain, raising the possibility that a large, early-maturing seed might alleviate quelea damage in some situations.

35. The concentration of total polyphenolics were determined in eight bird-resistant sorghums at four stages of development. Data indicated that reactive phenolics are produced during the milk stage, continue to increase in the dough stages, and decrease during ripening. Preliminary evidence suggests that this decrease occurs through loss of activity associated with polymerization. A cooperative study

has been initiated with investigators at the University of Arkansas to find bird-resistant properties effective during the immature stages of sorghum but not nutritionally deleterious in mature grain.

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