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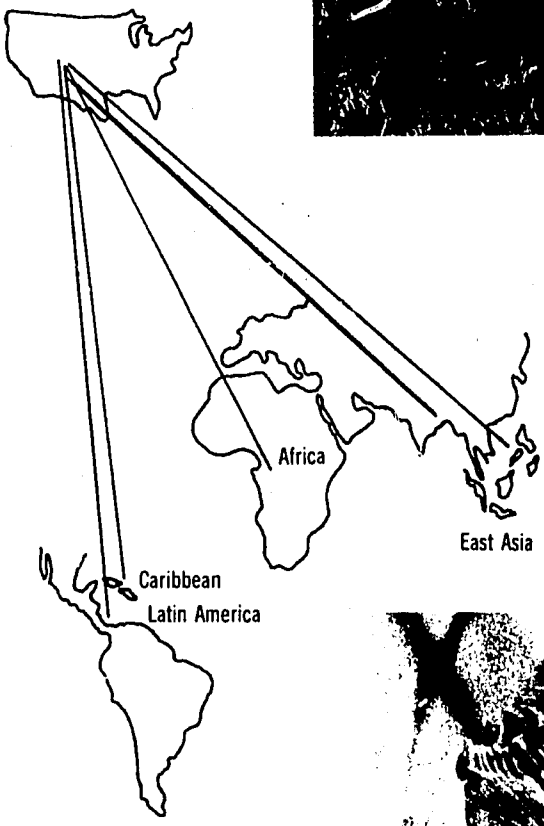
VERTEBRATE DAMAGE CONTROL RESEARCH IN AGRICULTURE

ANNUAL REPORT 1980



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SECTION OF INTERNATIONAL PROGRAMS

Edited by
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COOPERATING AGENCIES:

U.S. Fish and Wildlife Service

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International Agricultural Agencies

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The cover illustrates the broad international scope of the AID-sponsored International Programs of the Denver Wildlife Research Center (DWRC) and two of the most severe animal damage problems under investigation. Research at DWRC and in the field involves evaluation of different control methods including chemical, physical, cultural, or other techniques which have potential for providing positive benefits by reducing vertebrate damage in agriculture. The pest species, crop, farming methods, environmental factors, and a host of other considerations may influence the manner in which a particular problem is approached.

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 posthavest storage conditions. Field programs are involved in trying to reduce or alleviate this damage in several countries of South and Central America, Africa, and Asia.

In many areas of the world, rodent damage to field crops such as rice in Asia 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.

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. Actual 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 hard to predict. Red-billed quelea in Africa are perhaps the single most important vertebrate pest species in the world.

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VERTEBRATE DAMAGE CONTROL RESEARCH IN AGRICULTURE

INTRODUCTION

Food--in sufficient quantity for a rapidly increasing world population--is an important problem facing mankind. In some developing countries, the disparity between available food and population is both widespread and acute, despite the fact that about one-half of the world's population is actively engaged in agriculture. Millions of people in scores of nations still suffer hunger, malnutrition, and starvation. The reasons are many and complex, but certainly vertebrate pests (primarily rodents and birds) are important factors. Historically, they have not received the degree of attention given to other agricultural pests so that, with few exceptions, little reliable information on the species involved, degree of damage, and the economic impact, is available. Damage is, however, unquestionably calculated in hundreds of millions and perhaps billions of dollars annually.

In recent years, the role of vertebrate depredations in agriculture is attracting more interest in developing nations. Recognizing this, the U.S. Agency for International Development (AID) has supported a research program at the Denver Wildlife Research Center of the U.S. Fish and Wildlife Service (USFWS), since 1967 under a Participating Agency Service Agreement (PASA) as provided for in Section 632B of the Foreign Assistance Act of 1961 (Table 1). This DWRC research program's goal is to evaluate these situations and, when circumstances warrant, develop methods to reduce or eliminate the damage. For many years, DWRC has been recognized as a leading organization in researching vertebrate pest damage problems and developing useful tools for vertebrate pest management. Its problem-solving team approach has led to the development and use of new methods, materials, and techniques for vertebrate pest control, resulting in monetary savings in several developing countries.

The overall objective of this project is to increase the available human food supply in developing countries by reducing losses to vertebrate pests. The ultimate aim of the pest management research program is to develop safe, effective, and economical control methods which are suitable and practical for traditional farmers and acceptable in the broader context of agricultural development. Self-sustaining, in-country programs are the expected end result of this project. Program goals are accomplished by (1) in-country programs, (2) outreach activities from the DWRC as requested by AID/Washington, AID Missions, or host countries, (3) supervisory and administrative functions from the DWRC and AID Washington, and (4) problem-oriented research activities at DWRC through the Sections of Supporting Sciences, Bird Damage Control, Mammal Damage Control,

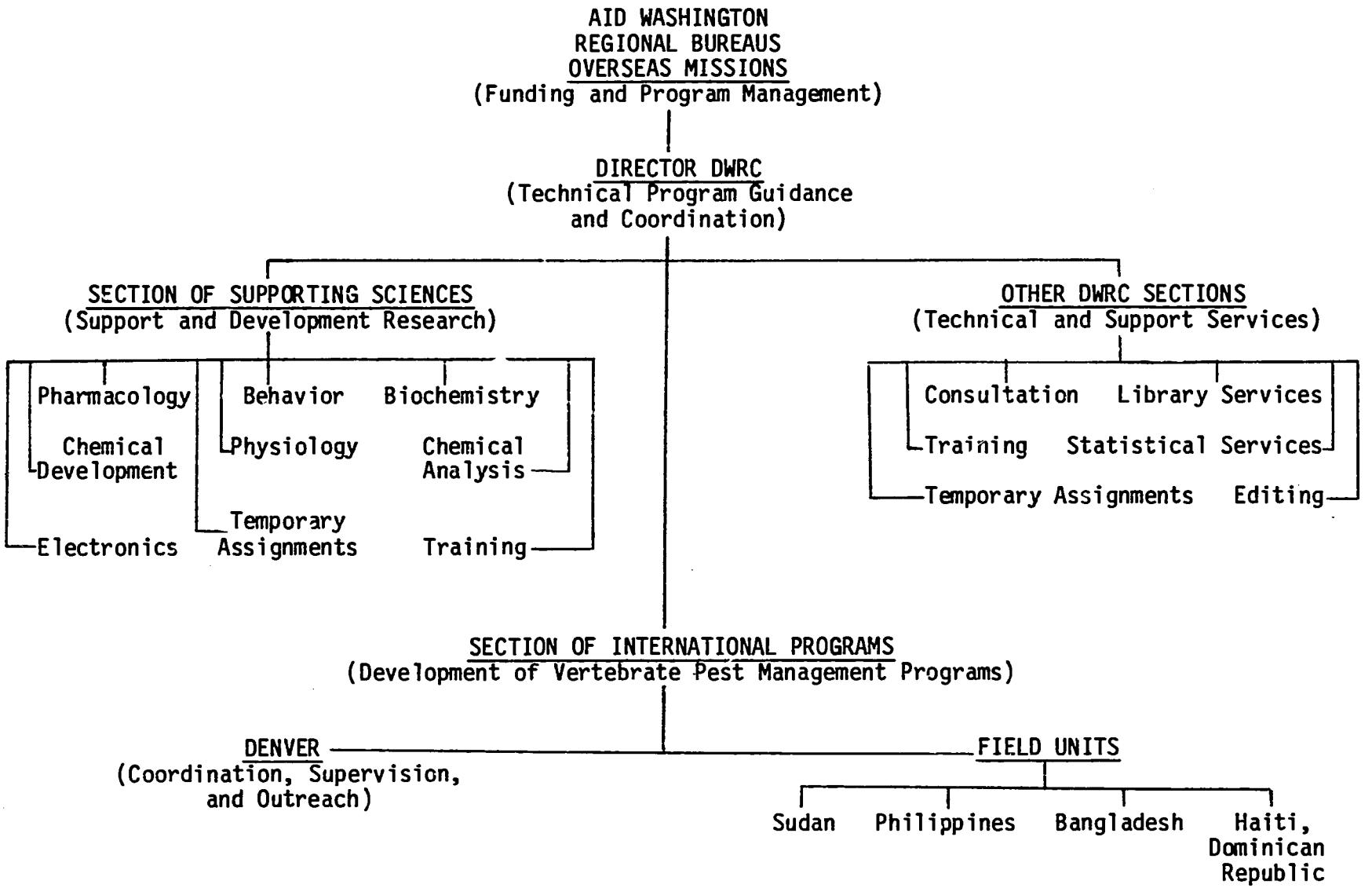
and other components of the Center. Vertebrate damage problems in Africa, Asia, and Latin America are continuously reviewed with the aim of adapting current techniques or materials to specific problem situations in a crop protection-oriented management program which will provide an effective means of long-term crop loss reduction.

The project incorporates a balanced but flexible program of applied research, technology transfer, and training. Research activities incorporate coordinated laboratory investigations at DWRC and selected laboratories in developing countries with associated field trials at appropriate sites in specific problem areas. A team approach, using the services of an interdisciplinary group of scientists and technicians with diverse backgrounds and experience, coupled with active involvement of foreign investigators, results in practical solutions suited to local requirements. In addition, it creates a favorable climate for continuing cooperation with indigenous institutions. Training of local counterparts and institutionalization of both research functions and implementation programs are viewed as integral parts of the overall project.

The Section of International Programs of DWRC 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. The experienced DWRC staff is comprised of specialists in diverse fields such as ecology, physiology, pharmacology, wildlife biology, nutrition, statistics, animal psychology and behavior, chemistry, and electronics. Several staff members have foreign experience and fluency in foreign languages. Denver Center laboratories are well equipped with the instrumentation necessary to conduct research in each of the disciplines involved. 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.

Throughout the report, reference to trade names does not imply endorsement by U.S. Government or cooperating foreign agencies.

Table 1. Organizational chart.



During 1980, project personnel devoted considerable time and effort to implementing and supporting the activities of field stations in Bangladesh, the Philippines, Sudan, and Haiti. DWRC also cooperated with organizations such as the Food and Agriculture Organization (FAO) and German Society for Technical Cooperation (GTZ) in vertebrate damage control research and training activities of mutual interest. In addition, the staff continued to assist AID in planning and technical assistance activities involving vertebrate pest management. At the request of USAID/Managua, DWRC helped the Government of Nicaragua assess rodent problems and lay the groundwork for outlining the requirements for implementing a vertebrate pest management program.

Latin America

To address the problem of vertebrate pest damage to agriculture in the Caribbean Region, the Latin America Bureau, AID/Washington established a regional program with special emphasis placed on those crops which are predominantly produced by traditional farmers. Memorandums of Understanding were signed during 1979 by the U.S. Government and the Governments of the Dominican Republic and Haiti. The project headquarters is in Port-au-Prince, Haiti to serve the specific needs of Haiti, the Dominican Republic, and other regional countries. If the results achieved under this program prove beneficial, other outreach centers could be established later for South or Central America.

Sudan

The Vertebrate Pest Research Project began in Sudan in May 1977. The project, with DWRC support, operates under an Agreement Between the Government of the United States and the Government of the Democratic Republic of the Sudan signed on 12 May 1977.

Since May 1979, the project has cooperated with the Agricultural Research Corporation (ARC). Facilities were renovated and experimental field sites made available. The project continued to maintain cooperative ties with PPD. As recommended by DWRC, project work has been prioritized and study plans have been written, reviewed, and implemented. Work on damage assessments and chemical crop protection of newly sown seeds and ripening grain was stressed. In September 1979, a wildlife biologist position was reestablished at DWRC with responsibility for coordinating bird control research activities in Sudan and other countries.

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Two Sudanese M.A. degree graduates returned from the United States in March 1980 and assisted greatly in project activities. Supporting research at Denver progressed as planned. Cooperation with FAO in East Africa continued for mutual benefit.

DWRC Biologist, Wayne Bohl, was reassigned to the United States after 4-1/2 years in Africa (3-1/2 years in Sudan). DWRC/USAID was requested by the Government of Sudan to examine the project's scope with the view of institutionalizing Integrated Wildlife and Vertebrate Pest Management Research. A replacement biologist will be recruited for this project if it materializes.

Bangladesh

DWRC Biologist, Richard Poché, returned to the United States in December 1980. Joe Brooks will assume leadership of the program in Dacca in early 1981.

Other

An AID Review of the project was held in Washington, D.C. in December. The review team consisted of Dr. William B. Jackson (chairman), Dr. Douglas Butchart, Mr. Lynwood A. Fiedler, Mr. William D. Fitzwater, Dr. Walter E. Howard, Dr. J. D. Montgomery, Ms. Essie S. R. Brown, Mr. Allan Hankins, Mr. Victor Lateef, Mr. W. Phillip Warren, Mr. John W. De Grazio, Dr. Clyde Jones, and Mr. Richard Smith. The review committee recognized the seriousness of vertebrate pests to world agriculture, the importance of the AID/DWRC program, and made recommendations for research objectives.

DWRC staff traveled in Africa, Asia, Caribbean, Central America, and Latin America during 1980. Travel was undertaken in conjunction with ongoing field research activities and at the request of foreign governments through AID Missions or AID Washington, to participate in international meetings, assess vertebrate pest problems, or to review, evaluate, and coordinate present and future research programs. TDY activities from the DWRC have become an increasingly important part of the project and DWRC will continue to respond to such requests through AID. Many types of short-term evaluations and cooperative studies with host-country scientists may be carried out expeditiously in this manner. This travel involved 245 man-days in the following countries:

Kenya	Bangladesh	Dominican Republic	Mexico	Italy
Senegal	Philippines	Haiti	Nicaragua	United Kingdom
Sudan				
Tanzania				
Comoro Islands				

Travel dates, persons involved, countries visited, and the purpose of each trip are outlined briefly in Table 2. Detailed information is contained in individual trip reports on file at the Denver Wildlife Research Center, Section of International Programs.

Table 2. International travel on technical assistance projects by AID/FWS-DWRC personnel during 1980.

Date	Traveler	Destination	Purpose of Visit
8-18 Jan	I. Okuno	Philippines	Provide technical assistance to USAID and NCPC in procurement of laboratory equipment and instruments for their Human and Environmental Safety Laboratory.
6-24 Feb	J. W. De Grazio	Sudan	Participate in and contribute to a project evaluation requested by USAID Sudan Mission. Review and resolve research and administrative matters.
16 Feb-13 Mar	R. T. Sterner	Bangladesh, Philippines	Provide assistance in field research in Bangladesh. Plan and coordinate behavioral research in the Philippines.
2-21 Mar	G. C. Mitchell	Nicaragua, Haiti	Assess rodent damage problems in rice and other crops; discuss possible actions with USAID and Government of Nicaragua personnel. Discuss research plans for Caribbean regional vertebrate pest management project with Government personnel of Haiti.
24 Mar-20 Apr	J. W. De Grazio, R. D. Thompson	Bangladesh, Philippines	Review status of research studies and assist in planning future activities in Bangladesh and the Philippines.

Table 2 (cont'd)

Date	Traveler	Destination	Purpose of Visit
29 May-13 Jul	R. L. Bruggers	Senegal, Sudan, Kenya, Tanzania, Italy, United Kingdom	Senegal: Discuss research programs with various agencies and University of Dakar. Sudan: Provide technical assistance in field research. Discuss possible cooperation in M.S. degree program in Crop Protection at University of Gezira. Kenya: Discuss cooperative research programs with UNDP/FAO personnel and University of Nairobi. Tanzania: Organize cooperative methiocarb bird repellent work; conduct preliminary radio telemetry trials. Italy: Meet with FAO Plant Protection personnel. United Kingdom: Discuss Curb, a chemical bird repellent, with manufacturer.
1-16 Jun	J. B. Bourassa	Haiti, Dominican Republic	Train Haitian counterparts to conduct tests of prototype transmitters. In Dominican Republic lecture and conduct field exercises on use of wildlife telemetry equipment.
13 Aug-13 Sep	P. J. Savarie	Bangladesh, Philippines	Assist in planning and conducting rodent control studies in Bangladesh. Consult on parallel studies being conducted in Denver and Los Baños, Philippines.
5-18 Sep	J. W. De Grazio	Sudan, Kenya	Clarify status of proposed 3-year bilateral Integrated Wildlife and Vertebrate Pest Management Research Project to begin May 1981. Provide assistance in research and administrative matters.
8-11 Sep	M. W. Hall	Mexico	Participate in USAID-sponsored Pest Management Workshop.

Table 2 (cont'd)

Date	Traveler	Destination	Purpose of Visit
13 Nov-13 Dec	M. W. Fall	Kenya, Comoro Islands	Discuss vertebrate pest control research in Kenya with FAO and World Bank personnel; participate in FAO technical meeting on bird damage control. Assist Comorean Government/World Bank project in establishing rodent control programs in coconut areas, upon request of the World Bank.
30 Nov-16 Dec	R. M. Engeman	Haiti, Dominican Republic	Assist in designing method of assessing vertebrate pest damage to rice, corn, and sorghum in Haiti, and sorghum in the Dominican Republic.

Four field projects, involving resident U.S. biologists, operated during 1980 under the AID/DWRC program. These projects were located in the Philippines, Sudan, Bangladesh, and Haiti/Dominican Republic. The broad goals of these projects are to increase food production and to reduce the risk of severe agricultural losses caused by vertebrate pests in developing countries by:

1. Developing practical, low-cost control methods for specific vertebrate pest situations in affected regions.

2. Adapting existing methods and technology to specific agricultural situations.

3. Investigating progress and problems of implementing programs involving modern vertebrate pest control techniques.

4. Developing indigenous capabilities for evaluating control methods and managing program implementation.

5. Working with country, regional, and international institutions to develop long-term institutional support for implementing, evaluating, and continually reassessing vertebrate pest management programs.

BANGLADESH

During 1979, work centered on completing the Vertebrate Pest Division headquarters, recruiting counterparts, assessing rodent damage to wheat, evaluating several rodenticides, conducting trials for controlling rodents in deepwater rice, and initiating preliminary trials with methiocarb as a seed dressing to reduce losses by birds to sprouting wheat. During 1980, with the completion of construction of headquarters and the filling of counterpart positions, several of these studies were expanded upon and some new ones were initiated.

Comparing Food Preference Evaluation Techniques for Lesser Bandicoot Rats (*Bandicota bengalensis*)

The objective of this laboratory study was to evaluate three methods of presenting food to lesser bandicoot rats (*Bandicota bengalensis*). The results have implications to rodenticide testing. Three male and three female rats averaging 260 $\pm$ 10 g were used. Food was presented to the rats in three ways: (1) single cup--only one food item was given on 2 consecutive days; all three grains were provided in sequence during 6 days; (2) double cup--two types of grain were provided in two cups (spaced approximately 10 cm apart) with all possible grain combinations provided for 2 days each; and (3) triple

cup--all three types of grain were provided simultaneously in individual cups over a 2-day period. For these methods, 30 g of either whole polished (husked) rice, unpolished rice, or wheat grain was provided in individual food cups and their consumption by each rat recorded daily.

Average daily grain consumption by the rats was 15.2 g (single cup), 17.7 g (double cup), and 17.3 g (triple cup). In combining the double- and triple-cup consumption data 46.1% (391.1 g) of test food consumed was polished rice, 38.8% (329.6 g) was unpolished rice, and 15.1% (128.3 g) was wheat (Table 3).

Table 3. Average daily food consumption (g) of lesser bandicoot rats when presented food items individually or in combination.

Rat	Single cup	Double cup	Triple cup
R-1	15.0	18.1	15.6
R-2	15.7	17.3	18.6
R-3	14.5	17.7	18.2
R-4	15.0	17.7	16.9
R-5	15.4	17.6	16.2
R-6	15.3	17.9	18.2
Total	90.9	106.3	103.7
Avg	15.2	17.7	17.3

When only a single food item was presented daily, consumption ranged from 27.1 to 35.9 g over the test period for each rat. Consumption rates differed significantly for the three types of grain (ANOVA F = 57.32, P <0.001). Rats preferred unpolished rice over polished rice and wheat (P <0.001, paired t-test). No significant consumption differences were noted between polished rice and wheat (P >0.1)

Findings from the double-cup tests were different from the single-cup trial. Various three-grain combinations presented to the rats revealed that polished rice was preferred over unpolished rice (P <0.005), and that both polished and unpolished rice were preferred over wheat (P <0.001) (Table 4).

Although more variation was noted in the double-cup feeding trial, the method is recommended for future feeding or preference studies. Presenting rats with a choice of food items is more comparable to what they encounter in the wild. Although the triple-cup presentation method may be useful, the position of the cups and the habits of the rats may bias the results.

Table 4. Results of the double-cup preference test conducted over a 2-day period with three male and three female lesser bandicoot rats in Bangladesh.

Rat	Polished rice	Unpolished rice	Polished rice	Wheat	Unpolished rice	Wheat
R-1	19.8	18.9	30.5	8.0	24.5	7.0
R-2	20.7	16.7	29.0	6.0	23.5	8.2
R-3	19.3	17.6	28.9	8.8	21.5	10.5
R-4	18.9	17.9	29.5	8.0	21.0	10.8
R-5	20.2	16.8	30.1	7.9	22.7	7.9
R-6	20.6	18.2	29.4	8.1	25.0	6.5
Total	119.5	106.1	177.4	46.8	138.2	50.9
Avg	19.9	17.7	29.7	7.8	23.0	8.5

Comparing Techniques for Monitoring Small Mammal Abundance

The objective of the study was to compare two methods of monitoring rodent population abundance. For 20 weeks, on 2 consecutive nights, 50 snap traps and 50 inked tracking tiles were placed at dusk on a 2.5-ha island in the deepwater rice zone. Twenty tiles and traps were each set in dwellings, 10 were placed between dwellings, and 20 were set along the island periphery.

Trapping and tile data revealed no significant differences ($P > 0.05$, t-test) in rodent abundance between day 1 and day 2 for either technique; however, differences were evident among techniques ($P < 0.001$) (Table 5). The mean trap success was 1.8 for day 1 and 1.7 for day 2, indicating that the first night's trap success had negligible impact on the second night's success. Small mammal species captured included lesser bandicoot rats, greater bandicoot rats (*B. indica*), roof rats (*Rattus rattus*), house mice (*Mus musculus*), and musk shrews (*Suncus murinus*).

One night of sampling per week was adequate in long-term studies to monitor small mammal relative abundance in the deepwater rice region. The choice between using trapping or tracking tiles depends upon the purpose of the study. If trends in small mammal numbers are required, as in a bait efficacy trial, tracking tiles may be preferable. If data on species composition, sex ratios, and reproductive parameters are necessary, snap traps should be used.

Table 5. Comparison of snap traps and inked tracking tiles for monitoring small mammal abundance on 2 consecutive nights each week during 20 weeks in 1980 in the deepwater rice zone of Bangladesh.

Method	Night	Mean ($\bar{x}$)	Stand. dev. (SD)	Coef. var. (CV) (%)
Tiles tracked	1	3.30	1.56	47
	2	3.25	1.92	59
	avg	3.28	2.39	48
Mammals trapped	1	1.80	0.95	53
	2	1.75	1.48	85
	avg	1.80	1.05	59
Traps sprung	1	5.35	1.63	30
	2	5.30	2.00	38
	avg	5.33	1.58	30

Wheat Yield Reduction by Simulated and Actual Rat Damage

The effects of simulated rat damage (stem cutting) on wheat (variety Inia) yield were studied using a completely randomized block design (four blocks). Within each block, fields were subjected to four damage levels: 0 (reference), 10, 30, and 50% of stems cut. Damage was evaluated at stages of: tillering (33 days after sowing--DAS), booting (58 DAS), dough (75 DAS), and maturity (103 DAS). Yields of 160 1-m^2 plots from each field were compared using standard analysis of variance (ANOVA) and least significance difference (LSD) tests. Two enclosures, containing two and four lesser bandicoot rats, were placed in the wheatfield to determine the amount of damage inflicted by rats over a 15-day period.

This study demonstrated that rat damage does not significantly affect wheat yield until the late booting stage (Fig. 1) and that baiting in wheat before the booting stage may be unnecessary. During the tillering stage, yield in plots with 50% of the stems cut did not differ significantly from reference plots (Table 6). At booting, significant differences ($P < 0.01$) in yields were noted when >10% of the stems were cut. All yields from the cut plots differed significantly from the reference plot at maturity.

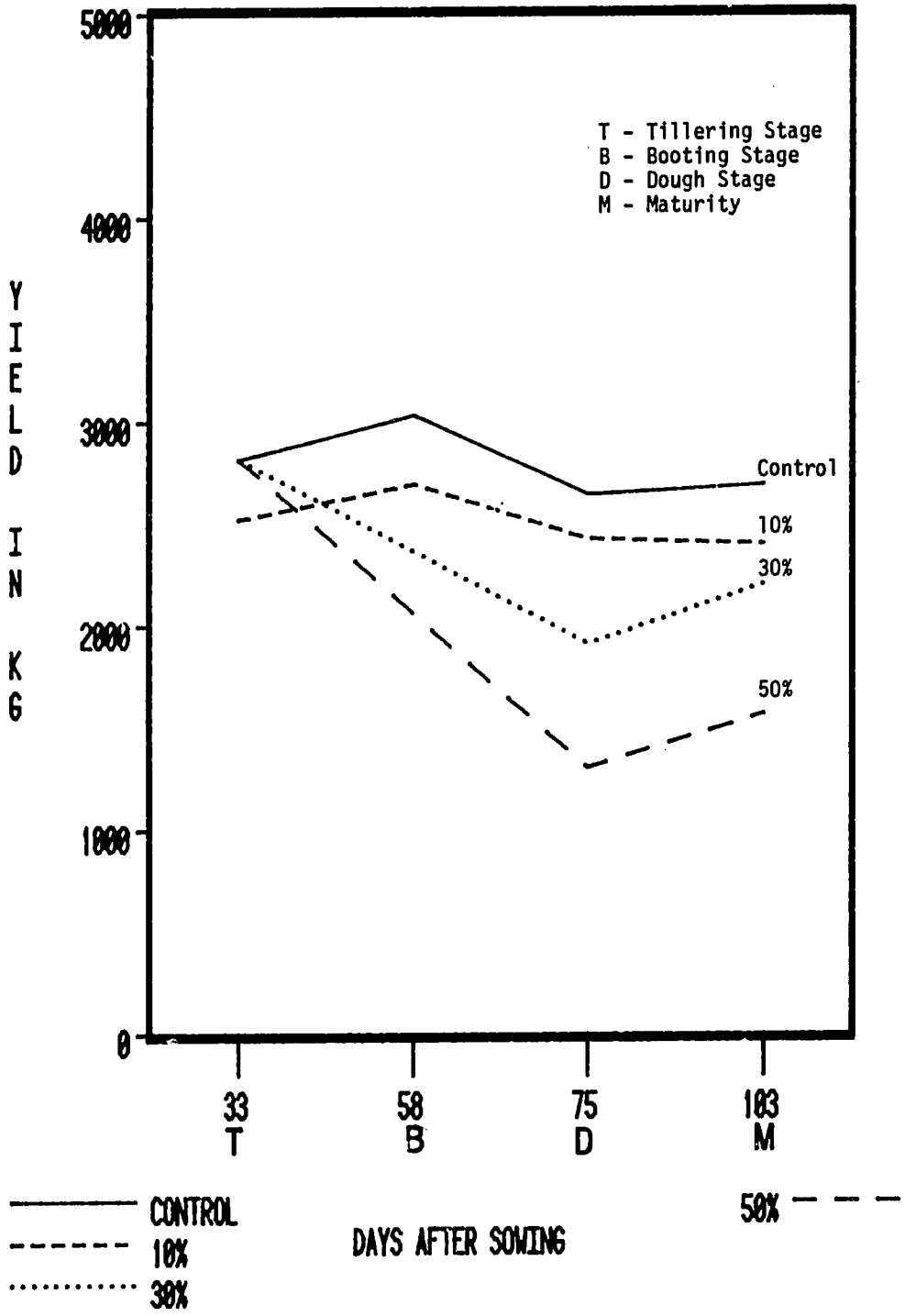

Figure 1. Yields from 160 1-m^2 plots of wheat, with 0, 10, 30, and 50% of the stems cut during four growth stages (tillering, booting, dough, maturity) in Bangladesh.

Table 6. Summary of wheat yields extrapolated from 160 1-m^2 plots (10 samples/plot) subjected to simulated rat damage by mechanical stem cutting in Bangladesh.

Growth stage	% simulated damage level	LSD tests* for: $\bar{x}$ yields (kg/ha) per damage level	LSD tests* for: Difference among growth stages	% deviation from reference
Tillering	0	2,800		-
	10	2,510^{ns}	ns	-10.4
	30	2,804^{ns}	ns	- 0.1
	50	2,797^{ns}	ns	- 0.1
	mean**	2,703^{ns}		
Booting	0	3,051		-
	10	2,697^{ns}	ns	-11.6
	30	2,349^{ns}	***	-23.0
	50	2,111***	***	-30.8
	mean	2,586***		
Dough	0	2,651		-
	10	2,415^{ns}	ns	8.9
	30	1,930***	***	-27.2
	50	1,305***	***	-50.8
	mean	1,883		
Mature	0	2,729		-
	10	2,412^{ns}	ns	-11.6
	30	2,223^{ns}	ns	-18.5
	50	1,586***	***	-41.9
	mean	2,074^{ns}		

* LSD tests for differences among damage levels; ns = not significant.
** Mean for treated plots only.
*** $P < 0.01$.

Lesser bandicoot rats can inflict heavy damage on wheatfields in a short time. In the enclosure with two lesser bandicoot rats, 86% of 3,610 wheat stems were cut by the rats within 15 days; 39% of these stems were stored in underground compartments along the burrows. The enclosure with four lesser bandicoot rats had 40% of 2,857 stems cut by rats and 38% cached.

Inexpensive zinc phosphide bait cakes were formulated, packaged, and made available to farmers in Gazaria Province for control of lesser bandicoot rats in wheatfields.

Rodent Movements in Wheatfields

Nocturnal movements of the lesser bandicoot rat, the greater bandicoot rat, and the roof rat were monitored using radio-telemetry. Two tracking stations were used to locate radio-equipped animals (Fig. 2). Lesser bandicoot rats were the most important pests and spent most of their time in wheatfields. Roof rats were restricted primarily to villages. Greater bandicoot rats moved between fields and villages. Radio tracking results from one field are shown in Figure 3 and indicate that the rats had small home ranges. The home range of the lesser bandicoot rat averaged 18 m^2 in mature wheat with high rat densities. Home range data indicate that the effectiveness of control with rodenticides will increase if baits are placed directly into or within 2 m of burrows. The mean functional period for the 5-g 164-MHz transmitters was 36.4 days (range 1-79 days).

Zinc Phosphide Bait Cakes

The Gazaria Thana region in Bangladesh was selected to evaluate a zinc phosphide baiting program with farmers to reduce rat damage to wheat. Approximately 1,500 farmers live in the 100-km^2 area. The bait was formulated using 48% wheat flour, 48% cracked rice, 2% zinc phosphide, and 2% edible oil. Rice and flour were mixed thoroughly, the oil was added, then the zinc phosphide. About 300 cm^3 of water/kg were added to this mixture to form a dough-like mass which was rolled out to 1-cm thickness, cut into 1-cm cubes, and sun dried for 1-2 days. Small plastic bags were made from locally purchased polyethylene sheets, candles were used to seal the edges of the bag. A packet contained 100 g of bait. The production cost of these bait packets was less than $0.07 each.

Bait packets were sold in Gazaria Thana and village markets during December. Participating farmers were provided with written and verbal instructions about safety and application methods. Two hundred bait packets were bought during a 2-hour period in one market.

Detailed field damage assessments and farmer interviews will be conducted in 1981 when the crop is mature to compare the effectiveness, applicability, and acceptance of the method with adjacent wheat-growing areas where the bait was not used.

Rodent Control in Wheatfields

The 1980 wheat crop, ordinarily planted in November and early December, was sown during late December because of heavy rainfall. A continuous area of flood plain wheatfields was selected in Gazaria Thana, 30 km SE of Dacca for rodenticide testing. Five study plots ranging in size from 0.68 to 0.89 ha were selected and were treated with either cyanogas, difenacoum, zinc phosphide, or brodifacoum; the fifth plot served as reference. Approximately 50 g of each bait

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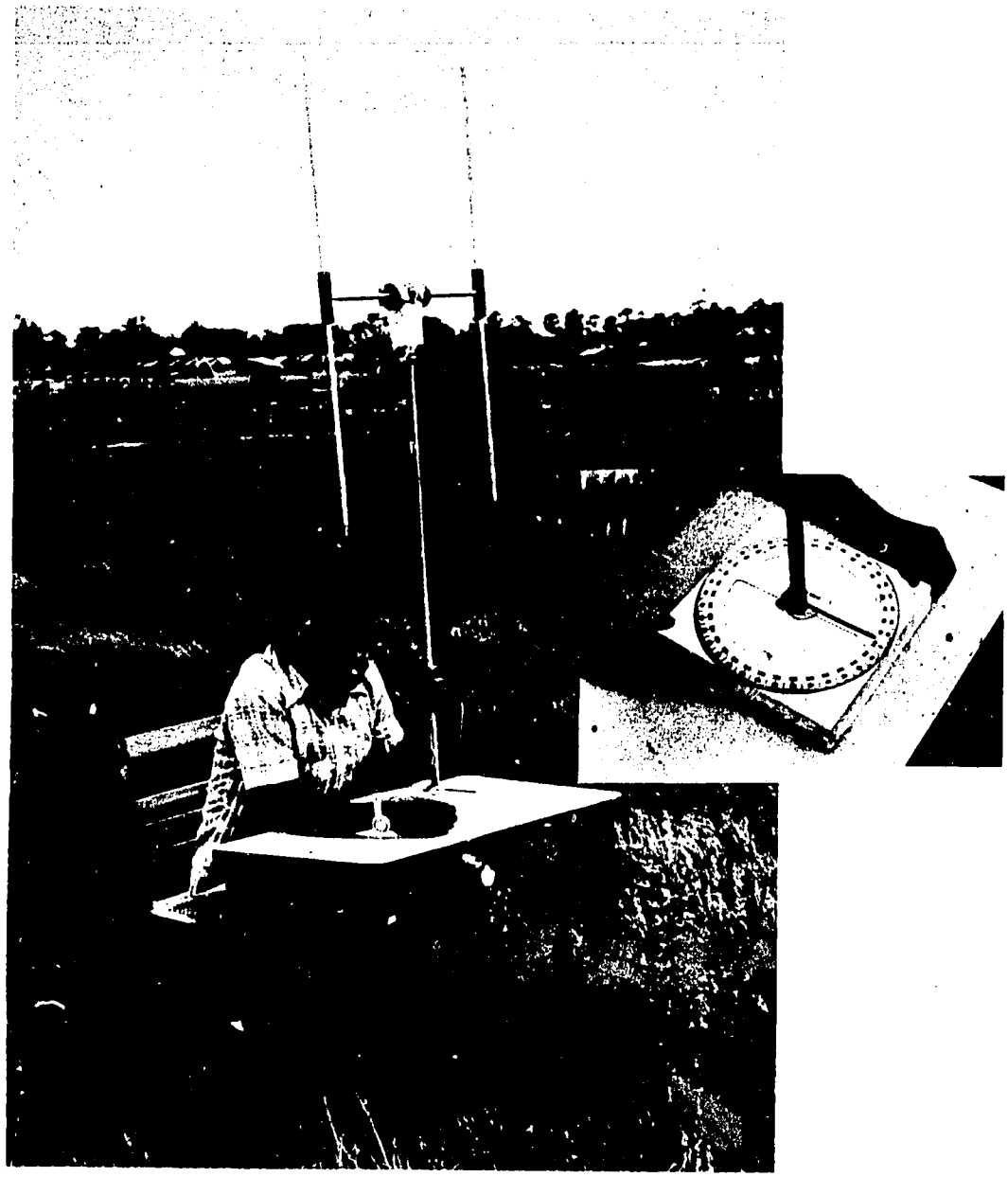

Figure 2. A portable radio tracking system was developed for monitoring the movements of rats in wheatfields and jackals in sugarcane in Bangladesh.

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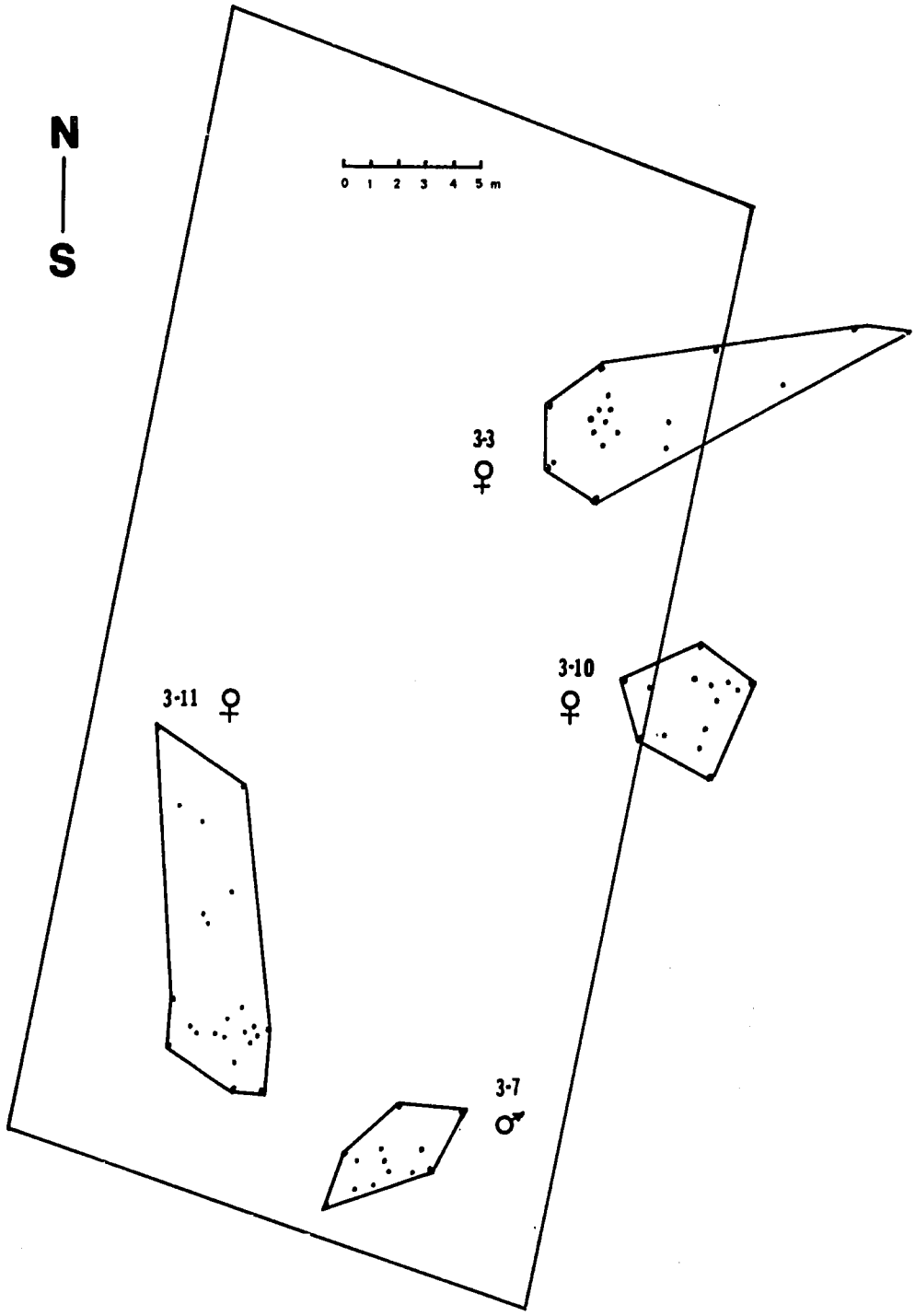

Figure 3. Radio recaptures of four lesser bandicoot rats on 8 March 1980 in a wheatfield near Agrakhola, Bangladesh. Movements were monitored from sunset to sunrise at 15-min intervals.

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was applied on banana leaves near the entrance to all active rat burrows in the plots during the late tillering stage. About 2 g of 25% calcium cyanide was placed deep into the burrows with an extended spoon, and the burrow entrance was closed with dirt. The number of cut tillers was determined in each field by extrapolation from counts made in each 200 m^2 of plot area using a 5,000-cm^2 sampling unit. An index of rodent activity was established in each plot using 25 tracking tiles for 2 consecutive nights each week until harvest. Snap traps also were placed in adjacent fields to determine the pest species involved.

Fifty-five rodents were trapped during 350 trap nights giving a trap success of 15.7%. Nearly all rodents were lesser bandicoot rats; only one greater bandicoot rat and one field mouse (Mus booduga) were captured. Rodent activity increased steadily with crop maturation (Fig. 4). Activity was highest during the harvest week in all plots. When the region flooded, the rats moved into villages or to other higher ground. Once the floods receded, the rodents slowly returned to the wheatfields.

Results of the control operation are presented in Table 7 and Figure 5. The least amount of rat damage (0.29%) was recorded in the difenacoum plot, and the most damage (1.29%) occurred in the brodifacoum plot. Rats damaged 3.2% of the reference plot. There was no significant difference between the treated plots ($r = 0.92$, $P < 0.05$) when examining stem density versus rat damage. As observed during 1979, lesser bandicoot rats preferred and caused more damage in fields with high stem densities.

Rodent Ecology in Deepwater Rice

Deepwater rice is grown during the summer months over about one-half of Bangladesh. Periodic heavy rat infestations in the flooded rice crop prompted a long-term study near the village of Agrakhola, about 10 km WSW of Dacca. Based on 31,092 trap nights, the most destructive rodent species to deepwater rice plants are the lesser and greater bandicoot rat. Other species trapped in the study area were the roof rat, house mouse, field mouse, soft-furred rat (Millardia meltada), and the little Burmese rat (R. exulans). Roof rats were abundant in villages but seldom captured in fields.

Annual rodent population cycles were bimodal in the deepwater rice zone and were influenced primarily by flood level (up to 4 m deep), rainfall, and available food resources. During the May 1979 to November 1980 study period, the rodent population abundance peaked in June 1979 and in February and October 1980 (Fig. 6). However, necropsy data showed that female lesser bandicoot rats were reproductively active throughout the year. Pregnancy rates for the flood periods were 12.2% in 1979 as compared to 26.1% in 1980 (Fig. 7).

Two trapping recommendations resulted from this study. Only 1 night of trapping using 50 traps is sufficient for monitoring rodent

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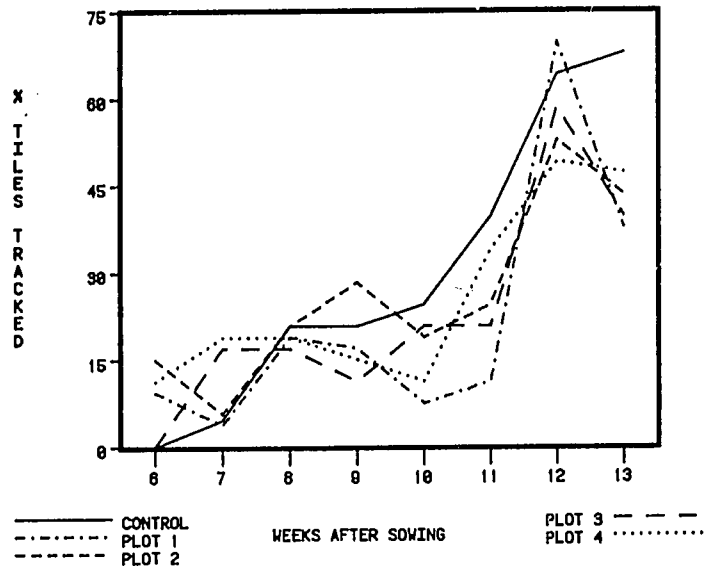

Figure 4. Tracking tile index for the five study plots: plot 1 (cyanogas), plot 2 (difenacoum), plot 3 (zinc phosphide), plot 4 (brodifacoum), and plot 5 (reference). In all plots, as the wheat crop matured, rodent surface activity increased, suggesting a dispersal from nearby higher ground and villages as the fields became dry. Since the study area lies in a deepwater rice flood plain, rodent control would be facilitated by controlling rats on higher ground and villages before the floods recede and rats move into nearby fields.

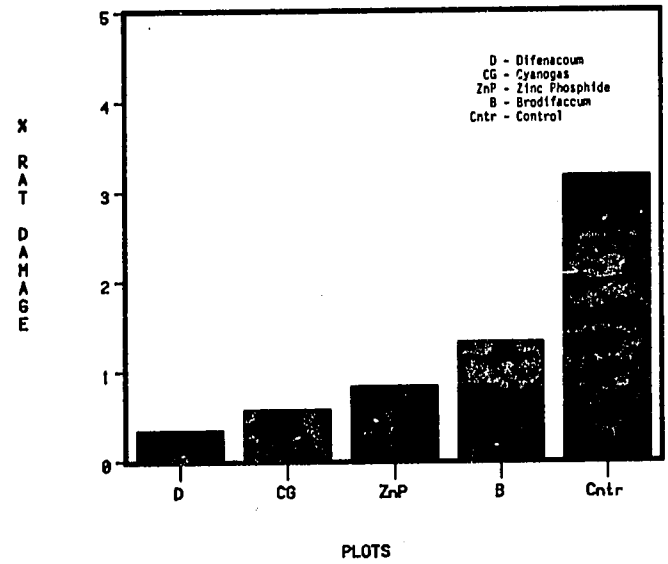

Figure 5. Results of the damage assessments in the five study plots in Gazaria Thana.

Table 7. Results of rodenticide and fumigant evaluations for rodent control in Bangladesh wheatfields during 1980.

	Treatment				
	Cyanogas	Difenacoum	Zinc phosphide	Brodifacoum	Reference
No. fields	8	8	6	5	6
Total area (ha)	0.89	0.68	0.75	0.69	0.72
No. 5,000-cm^2 sample units	46	32	46	24	50
No. uncut stems	6,561	4,436	7,579	4,055	8,148
No. cut stems	38	13	63	53	262
Total stems	6,599	4,449	7,642	4,108	8,410
% rat-damaged stems	0.58	0.29	0.82	1.29	3.10
Mean no. stems/m^2	286.9	278.1	332.3	342.3	328.2

numbers on islands in the deepwater rice zone, because no differences in capture success occurred between 1 and 2 nights of trapping. Seven nights of removal trapping (130 rodents per 3.3 ha of island area) also were sufficient to obtain accurate density estimates.

Rodents appeared to have specific habitat preferences based on the location of 736 rodents captured on the islands. More than 94% of the roof rats were trapped inside or between dwellings; 62% of the bandicoot rats and 73% of the musk shrews were captured between dwellings or along island peripheries, and 96% of Mus spp. were captured inside dwellings.

As in previous tests, rodenticides effectively eliminated 88-100% of most pest species. Intensive trapping showed some potential but was difficult and labor intensive. Control efforts must be continuous, because rodent numbers will build up rapidly if trapping or rodenticide applications are stopped.

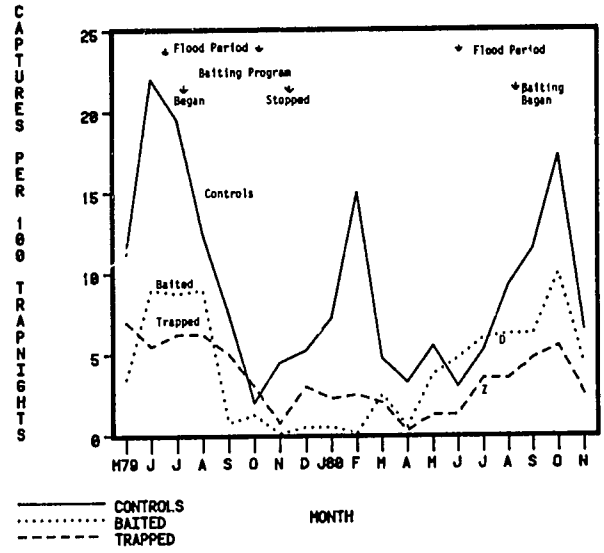

Figure 6. Monthly rodent population fluctuations in the deepwater rice zone study area. Data are based on trapping results from nine islands: three baited with rodenticides, three intensively trapped, and three controls. "D" represents the islands baited with DRC 4575 and "Z" zinc phosphide-treated islands. The study area underwent annual flooding (maximum of 1.8 m in 1979 and 3.3 m in 1980).

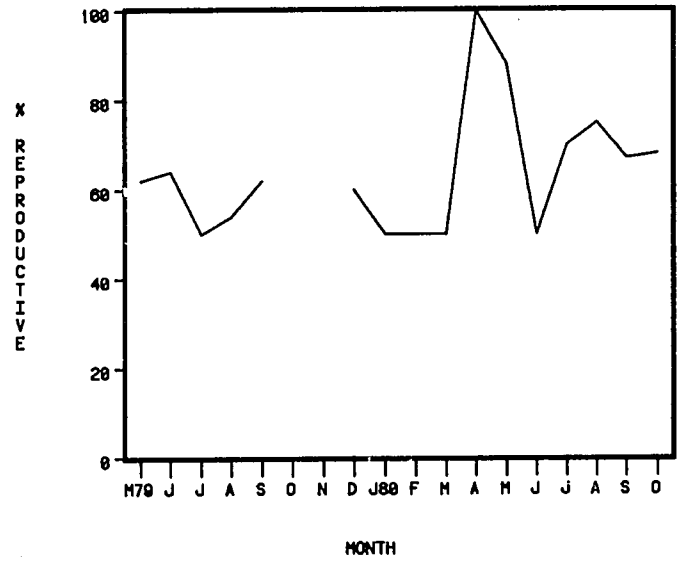

Figure 7. Reproductive pattern of Bandicota bengalensis from the deepwater rice study area.

This work suggests that rodent damage to deepwater ricefields may be reduced by applying baits on islands and high ground during periods of restricted rodent distribution and movements.

Cooperation with National and International Organizations

The Vertebrate Pest Division (VPD) staff held regular meetings with members of the Bangladesh-German (GTZ) rodent control project to discuss field and laboratory activities. Plans were initiated for cooperative large-scale rat damage assessments in rice and wheat crops.

A collaborative research project on rodent problems in deepwater rice was completed between the VPD and members of the Bangladesh Rice Research Institute (BRRI) and the British Overseas Development Administration (ODA). The study involved ecological investigations of several rodent species and rodent control trials using different rodenticides. The VPD also assisted BRRI in a local rodent control efforts at the Joydebpur deepwater rice tanks.

The VPD continued a joint research project with members of the Bangladesh Sugarcane Research Institute (SRI) in studies of jackal (*Canis aureus*) ecology in agriculture and short-tailed mole rat (*Nesokia indica*) damage to sugarcane and peanut crops.

Mr. Poché visited Thailand from 10-13 December 1980 to discuss rodent control activities with members of the Thai/German Rodent Control Program.

Personnel and Training

Md. Abdul Karim continued a Ph.D. program at Bowling Green State University, Ohio in Vertebrate Pest Management. His Ph.D. research will be conducted at the DWRC station in Hilo, Hawaii.

Md. Yousuf Mian began an M.S. program in Vertebrate Pest Management at the University of the Philippines at Los Baños (UPLB). His thesis research was completed on rodent control in deepwater rice in Bangladesh.

In early November, Md. Emdadul Haque also enrolled at UPLB in an M.S. program in Vertebrate Pest Management. Research he completed on simulated and actual rat damage in wheat will be used for his thesis.

The VPD staff spent numerous hours instructing BARI and IADS staff members in the preparation and use of zinc phosphide bait cakes used to reduce rat damage in experimental plots. Demonstrations of methiocarb seed treatments also were conducted to reduce bird damage to sprouting wheat.

The red-billed quelea is a serious pest to cereal farmers in Africa. Quelea range over about 20% of Africa and adversely affect the economies of 20 to 25 nations.

SUDAN

During 1980, the DWRC Vertebrate Pest Project conducted surveys to determine the movements, distribution, and damage of quelea, initiated fieldwork on chemical repellents, and began laboratory research on marking methods, repellents, and avicides. No rodent fieldwork was undertaken but summary documents of both the bird and rodent problem in Sudan were drafted.

The goal of DWRC work on red-billed quelea (Quelea quelea) damage in Sudan is the development of methods and programs for protecting cereal crops. Emphasis was placed on (1) developing appropriate, economical methods, suited for use on small or traditional farms; (2) appraising the nature and magnitude of quelea losses in Sudan; (3) assisting in the development of national research and control programs; and (4) coordinating activities with other international organizations to maximize results. Although the program is targeted for traditional farm situations, benefits for large or "modern" farm schemes are also anticipated.

Surveys and Damage Assessments

Project personnel made field trips from 4-12 March and from 17 September to 5 October to western Sudan in cooperation with the USAID-sponsored Western Sudan Agricultural Research Project. The first trip in March located traditional millet and sorghum farming areas that have experienced annual quelea damage. Damage estimates in 1977, 1978, and 1979 by farmers and Plant Protection Department (PPD) bird control officers for the grain areas of Kadugli, Lagowa, Talodi, Kologi, and Abu Gubeiha ranged between 20% and 80%, annually. Damage occurred between September and November each year. Areas with water, abundant grass seed, and good breeding sites received the heaviest damage. Quelea usually breed in the Kadugli area during September, a period which coincides closely with milk or dough stages of millet and sorghum.

During June and July 1980, the numbers of birds arriving at Soba Island (near Khartoum) and their feeding preferences were monitored. In June, the bird population on this island was estimated at 1.5-2.5 million, of which approximately 95% were golden sparrows (Passer luteus), 3-4% house sparrows (P. domesticus), and 1% red-billed quelea. Other species included doves (Streptopelia spp.) and glossy starlings (Lamprotonis spp.).

Crop content analysis of birds collected during this time indicated that golden sparrows were eating primarily wild seed and fodder sorghum. A few birds had eaten wheat which they presumably had gleaned from fields harvested earlier in February and March.

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Crop Protection Research Accomplishments

Several crop protection studies were carried out on sorghum, millet, and wheat at Agricultural Research Corporation (ARC) field stations at Shambat and Wad Medani. The work involved field enclosure tests and tests of application methods for repellents. In the enclosure tests, 20 2-m^3 wire cages were placed over undamaged heads in crop fields. Various trial applications were made, then 10 birds were maintained in each cage for up to 2 weeks.

Repellent Trials--Ripening Grain and Seed Treatments

Edge application of 2 and 6% methiocarb on sorghum.--Treatment with 2 and 6% methiocarb sprays of one edge, and 2 days later the remaining edges of a 0.1-ha sorghum field, markedly reduced the numbers of feeding birds during the first few days. Heads sprayed with either concentration were not eaten. Birds repelled included sparrows, and weaver birds of the genera *Ploceus* and *Euplectes*. The technique did not protect entire fields, because birds soon returned. After about 2 weeks, only the sprayed heads in the field were not completely eaten.

Edge application of methiocarb to protect ripening wheat.--Methiocarb was applied at the rate of 1 kg/ha to the outer edge (1/3 the area) of two 0.25-ha fields of ripening wheat. Two similar size fields were left untreated. Bird pressure and damage were monitored weekly.

Both treated fields were less damaged than their paired untreated fields, but in only one pair was the estimated yield significantly greater. From 18 to 21 times more birds were counted in the untreated than treated fields. Repelled birds probably shifted their activity to the untreated fields (Table 8).

Table 8. Crop damage and bird pressure in wheatfields treated with methiocarb, 21 February-29 March 1980, at Shambat, Khartoum, Sudan.

Fields	% of 1000 heads with damage	Avg no. birds visiting plots
Pair I		
Treated	3.1	3
Untreated	11.6	54
Pair II		
Treated	5.3	22
Untreated	46.0	463

Large feeding flocks of quelea can completely destroy fields of ripening crops in many African countries.

Comparison of edge and complete coverage application to ripening wheat.--Methiocarb was applied to experimental national wheat variety plantings at Shambat. All heads in 11 of 70 32-m^2 plots (352 m^2 total area) were individually sprayed with a total of 1.3 kg of methiocarb and 16 L of water; adhesive was not used. The edge rows of three other 32-m^2 plots also were sprayed to compare the effectiveness of edge and complete coverage applications. Damage was visually estimated before spraying and just prior to harvest. Comparisons were made between yield and damage patterns with wheat grown at Shambat during the same period during the previous 2 years when methiocarb was not used. Bird counts were conducted before and after methiocarb was applied.

Methiocarb elicited a repellent response by house sparrows, bishops, and *Ploceus* weavers. The number of birds observed in the study plots decreased from an average of 73 per 10-min observation (n = 7) during 3 pretreatment days to <1 bird per observation (n = 16) during 2 days immediately after the application. On the 10th day, the average was still <2 birds per observation (n = 6).

The reduced number of birds resulted in an average of only 2.9% loss in the 14 plots, compared with 5.6% in 12 plots in 1978/79 when methiocarb was not used. Five varieties grown in 1979/80 also were planted in 1977/78 and 1978/79. Four of these varieties received less damage in 1979/80 than in the 2 previous years (Table 9). None of the varieties were heavily damaged in any of the years. Finally, no significant differences ($P < 0.05$, t-test) occurred between the yields of edge-sprayed and completely sprayed plots (Table 10), again supporting the feasibility of the less expensive edge application methods.

Table 9. Damage to untreated (1977/78, 1978/79) and methiocarb-treated (1979/80) varieties of wheat at Shambat, Khartoum, Sudan.

	Avg % damage		
Wheat varieties	1977/78 untreated	1978/79 untreated	1979/80 treated
Mexicani	2.5	3.5	4.0
Son 64 XC - 271	1.3	0.9	0
Condor	3.8	1.5	1.8
Pato Argentina	1.2	0	0
Super Shambat	0	0.3	0
Nayab 70	1.5	0.8	0.5

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Table 10. Comparison of the effectiveness of complete and edge-only methiocarb applications to four varieties of ripening wheat, February 1980, at Shambat, Khartoum, Sudan.

		Spray coverage			
		Complete		Edge	
Wheat variety	Replicates	% loss	Yield (kg/32 m^2)	% loss	Yield (kg/32 m^2)
Mex XG 155 L2 75/76	1	0	9.5	0	7.9
	2	8.0	9.7	5.0	8.1
Son 64 XC - 271	1	8.0	10.1	5.0	10.9
	2	10.0	9.3	0.0	9.6
Mex XG 155 L15 75/76	1	0	10.7	0	9.2
	2*	-	-	10.0	9.5
	3*	-	-	5.0	8.6
Avg		3.7	9.8	3.6	9.1

* Only one complete-spray coverage plot.

Many farmers must rely on traditional methods such as covering heads with grasses to protect them from birds or calabas gourd-rattles positioned throughout a field to frighten the birds.

Methiocarb seed dressings for reducing losses to grain-eating birds to broadcast rice.--Farmers at the Gezira Scheme sow their fields at rates of 35 to 50 kg/feddan to compensate for various causes of nongermination, including bird damage; some fields must be entirely resown due to birds. Treating rice seed with an effective bird repellent would allow farmers to sow at the reduced rates and would probably also eliminate, in most situations, the necessity to resow.

A trial was conducted at the ARC station at Wad Medani. Two 600 m^2 adjacent bands in each of two 10-feddan ricefields were seeded at a rate of 35 kg/feddan. The seed for one of each pair of bands was treated with methiocarb (0.20% by seed weight) and Rhoplex AC 33 adhesives (48% solids--0.10% by seed weight) in a water solution in a barrel mixer, sun-dried, handsown into 7.5- to 10.0-cm furrows, and covered with 2-3 cm of soil. The fields were irrigated after 7 days, simulating planting conditions at the Gezira Scheme. Seeds and seedlings were collected for residue analysis at DWRC. Counts were made of the proportion of damaged to undamaged seeds, the number of plants, and the number of birds feeding in the trial fields during peak activity periods.

The principal bird pests eating the newly sown rice were chestnut sparrow larks (*Eremopterix leucotis*) and crested larks (*Galerida cristata*). They appeared to be part of a small resident population which averaged only 10-20 sparrow larks and 3-5 crested larks per day; 75% and 77% of the visits were recorded in the untreated plots. No quelea or golden sparrows visited the fields, although both species were in the area during the study.

Differences in the rate of seedling survival in the treated and untreated plots were not significant ($P > 0.05$) apparently due to displacement of seeds during flooding, a high proportion nongerminating seeds, and uneven distribution of seeds on and below soil. The effect of seed treatment on the seedling survival was probably obscured by these factors.

However, the proportion of damaged seeds was substantially greater in the untreated plots (11% and 22.9%--avg 16.9%) than in the treated plots (2.9% and 5.8%--avg 4.4%). Thus, the untreated plots received at least 3.8% times more damage than treated plots. The trial demonstrates that methiocarb can reduce rice seed damage by larks.

Seed and seedling samples for residue analysis of methiocarb and its sulfoxide and sulfone metabolites were obtained by randomly collecting at least 300 seeds or seedlings immediately after the chemical was applied and at days 10 (after irrigation), 15, 20, and 25 (when the plants were between 10 and 15 cm in height). The samples were immediately frozen and later sent by air to DWRC for analysis. A portion of each sample was analyzed 'wet' as received at the laboratory. The rest of the samples were dried, analyzed,

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and corrected to the wet weight basis. The results are presented in Table 11. Methiocarb residues from the dried samples were all ≤1 ppm after 15 days indicating no toxicity hazards. Differences of only 1-2 ppm were found between the wet and dry samples. The chemical already is registered in the United States for several fruit and grain crops at much higher levels of 15-25 ppm.

Table 11. Residues of methiocarb and its sulfoxide and sulfone metabolites (in ppm) from a 0.20% seed dressing treatment (by seed weight) of rice seed in Sudan, June 1980.

Growth stage	Time (days)	Wet sample Methiocarb	Dry sample Methiocarb	Dry sample Sulfoxide	Dry sample Sulfone
Presowing	0	0.11%	-	-	-
Nongerminated	10	2	9, 12	<1	<1
Seedlings	15	2	<1	<1	<2
Seedlings	20	3	1	<1	<2
Seedlings	25	<1	<1	<1	<1

Toxicity and Repellency of Starlicide, Avitrol, and Methiocarb to African Bird Pests

Golden sparrows, red bishops (*Euplectes orix*), and *Ploceus* weavers were sent to the DWRC laboratory in February for cooperative work with the Section of Bird Damage Control to determine the R50 and LD50 for the avicide, Starlicide; the frightening agent, Avitrol; and the repellent, methiocarb.

Ploceus weavers, golden sparrows, and red bishops showed differences in sensitivity to methiocarb. These species were, however, 4.2 to 11.8 times less sensitive than red-billed quelea (Table 12). This may explain some of the inconsistent results obtained in some methiocarb field trials involving these species.

The LD50's of Avitrol for all four species were less (1.78-4.22 mg/kg) than the LD50 previously determined for quelea (5.62 mg/kg). All four species exhibited typical Avitrol distress behavior and ED50's for distress were similar to the LD50's for all species except the golden sparrow.

Only a few field tests have been conducted in Africa with Avitrol principally because the lethal and distress-eliciting dosages for most of the pest species were unknown and because safe baiting and chemical application procedures needed further development. The promising results of the earlier field tests; in conjunction with these laboratory data, indicate that further field investigations of Avitrol baiting techniques may be desirable.

Table 12. Feeding repellency (based on number of birds repelled/number tested) for five species of African birds offered methiocarb-treated millet seeds. The percent consumption of food offered is given in parentheses.

Species, avg wt and range (g)	Treatment level (%)								R50 (%)	95% confidence interval (%)
	0.010	0.018	0.032	0.056	0.100	0.178	0.316	0.562		
Village weaver 34.9 (27.0-40.0)	-	-	0/4 (83.8)	2/4 (64.9)	3/4 (46.6)	-	-	-	0.063	0.038-0.100
Golden sparrow 14.4 (13.0-16.5)	-	-	-	-	2/6 (64.9)	4/6 (41.9)	3/6 (45.1)	5/6 (14.0)	0.178	0.075-0.420
Red bishop 15.2 (12.4-19.2)	-	-	-	-	1/6 (82.9)	5/6 (28.3)	4/6 (31.1)	-	0.133	0.077-0.230
Masked weaver 20.1 (17.0-24.0)	-	-	2/6 (73.9)	-	3/6 (57.7)	-	6/6 (14.9)	-	0.076	0.029-0.200
Red-billed quelea 21.5 (18.0-25.0)	0/5	4/5	4/5	-	4/5	-	-	-	0.015	0.011-0.021

Starlicide was found to be less toxic to the four species than to red-billed quelea. Because these species were relatively insensitive, Starlicide does not seem to offer a satisfactory alternative to other, more toxic avicides.

Testing the Repellency to Birds of a Combination of Methiocarb and Wattle Tannin

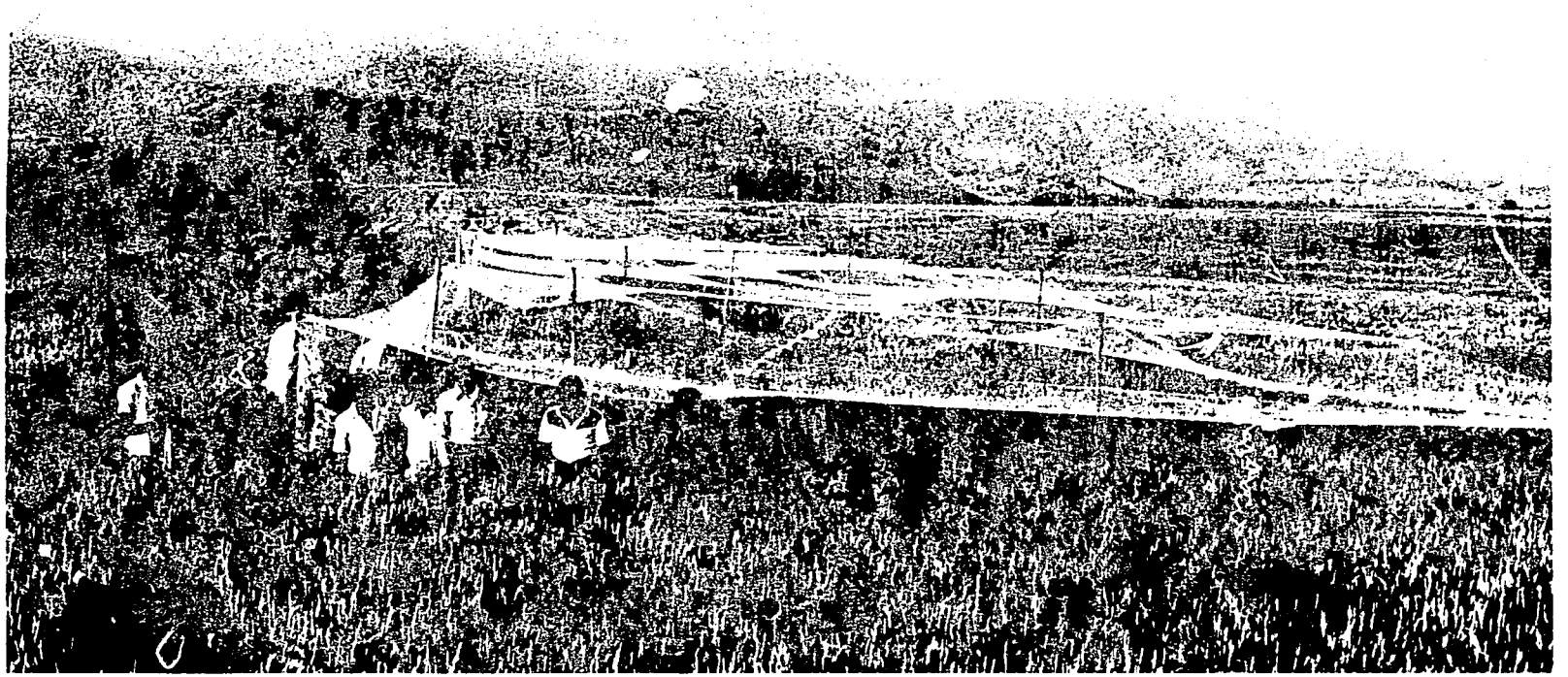
Although methiocarb has proven effective as a bird repellent in many situations, its cost may be prohibitive to many farmers. Wattle tannins, which are repellent to birds, occur naturally in Africa but also are commercially available and inexpensive.

This test was conducted to assess the repellency to quelea of a reduced amount of methiocarb combined with wattle tannin. Results of preliminary field cage tests of the repellency of this combination to birds were conducted during October and November 1979 on millet and sorghum; the results were very promising. The 1980 tests, conducted at ARC Shambat, were designed to provide new information on the effectiveness of the mixture on wheat and sorghum grains at different developmental stages.

Test procedures duplicated those used in 1979. Eighteen 2-m^3 cages (1 x 1 x 2 m) were placed over comparable growth stands of wheat providing three treatment types of three cages (1% methiocarb-adhesive, 5% methiocarb-1% tannin-adhesive, and untreated) for each of two maturation stages. The heads in nine of these cages were sprayed during the milk stage and those in the remaining nine cages were sprayed during the dough stage. Ten quelea were placed in each cage after the methiocarb was applied and given alternate food and water. In addition, each treatment was applied to 25 m rows of wheat in the field.

Both treatments resulted in an increased yield (Table 13). The methiocarb treatment reduced damage by 80.3% and 82.9%, respectively, at the milk and dough stages of the wheat crop. A comparable rate of damage reduction (85.1% at the milk stage and 97.8% at the dough stage) was associated with the methiocarb-tannin combination.

The weight of the 25 head samples resulted in 1.7 times more grain with the methiocarb-treated than in the untreated samples during both the milk and dough stages; the methiocarb-tannin treatment also increased the yield at the milk and dough stages by 2.1 and 1.7 times, respectively.



Plastic or cotton netting, when properly installed over portable support structures and regularly maintained, can effectively prevent birds from damaging cereal crops.

Table 13. Mean percent damage and yields from cage and field tests evaluating the protection of different methiocarb treatments applied at two maturation stages against pest birds on ripening wheat, February-March 1980, in Sudan. Cage treatments were replicated three times.*

		Treatment type			Exposed heads	
	Stage	Methiocarb + adhesive	Methiocarb + tannin + adhesive	Untreated	Treated	Untreated
% damage	milk	7.0	5.0	35.5	-	-
	dough	4.5	0.7	26.4	-	-
wt (g) of 25 heads	milk	33.0	41.0	19.0	-	-
	dough	33.3	33.3	20.0	-	-
wt (g) of 1 m^2	milk	236.3	312.6[a]	191.0[b]	-	-
	dough	283.0[a]	224.0	178.0[b]	-	-
	mean	259.6[a]	268.3[a]	184.5[b]	-	-
wt (g) from 25-m rows	milk	-	-	-	1,061	881
	dough	-	-	-	1,103	1,106
	mean	-	-	-	1,082	993

* Duncan's Multiple Comparisons (0.05 significance level). Any two means with different superscripts are significantly different.

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Based on the complete harvest of the wheat inside the enclosure, in the milk stage the effect due to methiocarb-tannin was significantly greater ($P < 0.05$) than for the untreated wheat. Contrastingly, in the dough stage, the effect due to methiocarb alone was significantly greater ($P < 0.05$) than for the untreated wheat. Thus, it appears that the methiocarb-tannin combination afforded better protection to wheat when applied at the milk stage. Moreover, the less expensive methiocarb-tannin combination elicited repellency to caged quelea equivalent to that elicited by the more expensive methiocarb-only formulation. This repellent combination will soon be evaluated over an entire field.

Preliminary Testing of Radio Transmitters for Quelea Movement Studies

Numerous situations exist in Africa in which a better understanding of the local and seasonal movements of quelea and other Ploceid weavers could increase our knowledge of bird behavior and increase the efficiency of crop protection operations. Radio telemetry has been very useful for obtaining such information for bird pests in the United States and may be appropriate for certain situations in Africa. Baseline data were obtained on the battery life, frequency stability, and ground and air reception distances of 1.7- to 1.9-g miniature radio transmitters built at DWRC. The ability of quelea to carry radios and the retention of tail and leg attachment methods were evaluated in flight cages. The battery life was 2.5-3.0 weeks. The pulse rate was relatively stable, but the frequency setting tended to shift with temperature fluctuations. The maximum ground and air reception distances were 5.6 km and 30.5 km, respectively (Table 14). Quelea carried radios weighing up to 9% of their body weight. Results were better when the radio was glued to the base of the tail than when attached to a leg (Table 15). These results suggest that field use of these radios for quelea studies will be possible during 1981.

Cooperation with National and International Organizations

A cooperative DWRC/FAO/BGSU research trial was organized to try to protect wheat farms in Tanzania with methiocarb from birds. A method of applying the chemical only to those areas (spots) on the farms actually being attacked was evaluated. Mr. Joseph Ndege, an FAO-sponsored Tanzanian M.A. candidate at Bowling Green State University, returned to Tanzania for the summer to conduct the research. He concentrated his efforts at the 380-ha USAID-sponsored Arusha Foundation Seed Farm and a 1,125-ha private wheat farm on the western slopes of Mt. Kilimanjaro. The data are being analyzed.

DWRC also hosted seven FAO-sponsored fellows from Kenya, Somalia, and Sudan, and three FAO project biologists for short periods to familiarize them with the Center's activities and develop possible cooperative research in areas of mutual interest. Several projects, such as using Microtaggants in Ethiopia and a sensory cue/methiocarb

Table 14. Maximum aerial reception distances obtained from 1.7-1.9-g radio transmitters attached to the legs (one antenna) and tails (one vertical antenna and one horizontal antenna) of quelea and tested on 28 and 29 June 1980, Arusha, Tanzania. Signals were received using one yagi antenna attached vertically to the wing strut of a Cessna 185-F aircraft.

Alt (m)	Plane speed (km/h)	Type radio	Reception distances (km): Parallel to antenna (W) Outbound	Parallel to antenna (W) Inbound	Perpendicular to antenna (N & S) Outbound	Perpendicular to antenna (N & S) Inbound
153	129	leg	2	3	3	7
		tail	8	8	11-12	11-16 (strong at 11)
305	129-140	leg	3	5	8	9 (strong at 8)
		tail	10	5-8*	12-13	11-24 (strong at 20)
610	137-140	leg	4	5	10	11-12
		tail	10	9-11	19-21	22-27 (strong at 24)
915	140	leg	5	8	8 (in clouds**)	11-12 (faint)
		tail	11	9-12	11-13	22-24
1220	177	leg	5	-	-	11-12
		tail	11-13	-	-	24-27
1525	177	leg	8	8-9	-	11-12
		tail	11-18	14-18	-	27-31

* If plane circled perpendicular to radio antenna.

** Clouds at 915 m.

\- Indicates that no attempt was made to locate the signal at altitude.

Table 15. Retention and weight change of red-billed quelea equipped with surrogate radio transmitters in an outdoor flight cage, June-July 1980, Arusha, Tanzania. Sample sizes are indicated in parentheses.

Attachment method	Avg wt (g) of radio	Avg wt (g) of birds Day 1	Day 7	Day 18	Comments*
Leg					
Adults	2.07	18.6 (5)	17.9 (3)	20.9 (1)	4 escaped, 1 died (broken leg)
Juveniles	2.10	18.1 (3)	16.4 (3)	16.5 (1)	1 escaped, 1 died
Total avg	2.08	18.4 (8)	17.0 (6)	18.7 (2)	
Tail					
Adults	2.03	17.7 (3)	18.2 (3)	19.7 (1)	tails of 2 birds dislodged**
Juveniles	2.03	18.4 (4)	19.8 (4)	22.9 (2)	1 died, 1 escaped
Total avg	2.03	18.1 (7)	19.1 (7)	21.8 (3)	
Reference					
Juveniles	no radio	17.3 (5)	18.8 (5)	20.3 (5)	all healthy

* Weights of dead birds or birds losing radios are not included in averages.
** Radio removed when tails dislodged during weighing.

combination spray to ripening crops in Senegal, already have been initiated; others are foreseen. We continued to cooperate in the international graduate training programs in Vertebrate Pest Management at Bowling Green State University and are assisting in the development of similar programs at other institutions.

Personnel and Training

Messrs. Mohamed Hamza Zein and Saeed Mohamed Suliman completed their M.A. degree programs at Bowling Green State University, and returned to the Plant Protection Department in Sudan.

Dr. G. A. Zorgani of the ARC Insecticide Residue Analysis Laboratory visited DWRC between 2 and 16 April to work with staff of the Chemical Research and Analytical Services Project. He assisted in conducting residue analyses of methiocarb and studied the analytical procedures used by DWRC. A list of supplies and equipment needed for residue analyses by the ARC laboratory in Sudan was prepared and many of the necessary materials have been obtained.

PHILIPPINES

Evaluation of 4-Aminopyridine as a Bird Control Agent

In the Philippines, three species of mannikins, the nutmeg mannikin (*Lonchura punctulata*), the white-breasted mannikin (*L. leucogaster*), and the chestnut mannikin (*L. malacca*), and the European tree sparrow (*Passer montanus*) are destructive to maturing rice and other cereal grains.

The chemical frightening agent 4-Aminopyridine (4-AP) has been used in other parts of the world to control bird damage. Birds ingesting bait treated with 4-AP emit calls and fly erratically, frightening the other birds in the flock. The purpose of this study was to evaluate 4-AP as a frightening agent to *Lonchura* spp. in the Philippines. The LD50 of 4-AP to each species was determined. Their behavior and their reaction to recorded calls were evaluated and limited field tests were conducted.

The LD50 of the four species to 4-AP was determined by standard techniques. From four to six birds per species received a 10 ul/10 g body weight volume by gavage. Nutmeg mannikins, the smallest of the three species of weaver birds, were the least sensitive to 4-AP, and white-breasted mannikins, the second largest species, were the most sensitive (Table 16). The LD50 for *P. montanus* (3.54 mg/kg) was twice as great as that previously reported for the house sparrow (7.5 mg/kg).

Table 16. Acute toxicity of 4-Aminopyridine to four species of Philippine birds.

Species	No. birds	Mean body weight (g)	LD50, mg/kg (95% CL)
L. punctulata	24	10.5	7.94 (5.47-11.52)
L. malacca	18	12.4	4.45 (3.33- 5.97)
L. leucogaster	24	11.5	3.11 (2.62- 3.69)
P. montanus	12	19.3	3.54 (1.84- 6.80)

The varying degree of sensitivity to 4-AP by the three species of weaver birds is evident in their behavioral responses. Five of six white-breasted mannikins, the most sensitive species, vocalized in the first 30 min after receiving 5-mg/kg dose level. Nutmeg mannikins, however, required a dose level of 20 mg/kg before all birds emitted distress cries. Avitrol elicited a distress response from European tree sparrows at the 5-mg/kg level.

Rice baits treated with 0.5% and 1.0% 4-AP were evaluated on European tree sparrows by feeding one kernel of treated rice to each of six birds. Birds receiving the 0.5% treatment emitted an average of 19 distress calls between 53 and 120 min or about twice the number emitted by birds given a 1.0% treatment. The 1.0% treatment resulted in more audible cries, but death occurred within 21 to 41 min (Table 17).

The calls of European tree sparrows that were orally gavaged with 4-AP/propylene glycol solutions were recorded and played back to sparrows eating rice in a warehouse of the National Post Harvest Institute for Research and Extension (NAPHIRE) and the National Grain Authority (NGA). Approximately 250 European tree sparrows were inside the 4,400 m^2 building. The taped calls were played over two cassette recorders for approximately 20 min; within 10 min all birds had moved to the opposite side of the building. The results were sufficiently encouraging that 4-AP was field tested again against European tree sparrows that were damaging sorghum at the Institute of Plant Breeding (IPB). A 1.0%-treated bait diluted with untreated bait at 1:50 was broadcast along 100 m of road just before sundown. The following morning, several affected birds were observed and other members of the flock showed the classical behavioral pattern of momentarily hovering over the affected birds and then flying away. The majority of the birds left the area in 10-15 min. Additional field tests are needed but this response indicates that 4-AP baits may be useful in reducing damage by European tree sparrows.

Evaluation of Bird Glues

The initial study that evaluated a local bird glue in rice paddies was reported in 1978. Birds landing on the glue emitted calls causing other members of the flock to leave the area. However, a major problem was that the glue lost its adhesiveness after only 2-3 days.

Recent studies with commercial glues also have produced poor results. Three glues have been tested, two in the laboratory and one in the field. Several birds (*Lonchura* spp.) were released into a small (0.5 x 0.5 x 0.5 m) wire cage containing commercial fly tape that was secured to a horizontal wooden perch. The birds became stuck, then fell to the ground with their feet and wing feathers entangled. No calls were heard. Birds also became stuck in Trap Stick^R but remained on the perch only until the glue began to run. One bird emitted a single call.

A third glue, TAK-too^R, was applied to several glue-coated wooden perches that were tied horizontally to the top strand of a wire fence along a sorghum field that was sustaining heavy losses by European tree sparrows. The following morning several birds were found sitting quietly in grass near the fence. No birds were stuck to the perches. It appeared that temperatures above 33°C and humidity above 85% adversely affected the glue.

Table 17. Responses of *Passer montanus* dosed with 4-AP-treated rice. Six birds were used for each treatment; all birds died following treatment.

4-AP treatment level		Avg body wt	Avg time to 1st distress call (min)			No. birds emitting calls			Calls		
$\bar{x}$ (mg/kg)	Percent	(g)	min.	max.	$\bar{x} \pm$ SD	0-30 min	31-60 min	61-120 min	Avg no.	Avg length (sec)	Range (sec)
4.4	0.5	20.3	14	49	28.2 ± 12.1	4	2	0	19.2	13.9	1-300
9.8	1.0	18.3	13	24	17.5 ± 4.5	6	0	0	9.2	19.3	1-240

Evaluating a Topical Application Method for Reducing Rodent Damage to Rice

Additional evaluation of a contact delivery method for rodenticides was undertaken in five rice paddies in Santa Cruz, Laguna that were receiving heavy damage. Damage in each plot was assessed about 3 weeks before harvest and treated with either 10% zinc phosphide in used motor oil, 20% zinc phosphide in used motor oil, 10% zinc phosphide in grease, 20% zinc phosphide in grease, or untreated motor oil and grease. Rhodamine B dye was added to the oil and grease to indicate if rats were contacting the formulation.

Thirty contact application points were placed along the dike and perimeter of the paddy. Three grams of the formulation were applied to 15 x 15-cm tiles and positioned across runways. Twenty tracking tiles also were spaced around the perimeter of the paddy to monitor rat activity. Pretreatment tiles indicated many rat crossings. Pretreatment activity was about 80% in all plots and damage ranged from 3.8 to 18.6%. Three days after the initial treatment, rat activity remained at 80%. Because of such high activity, 30 extra treatment tiles (60 total) were placed in two plots. Rat activity remained high for 3 days. Damage in three of the plots 2-3 days before harvest was 24-35% (Table 18); several fields were completely destroyed and two fields were harvested early to save the crop.

Table 18. Percent cut tillers at before and after zinc phosphide treatments in mature ricefields receiving heavy rat damage.

Treatment	% cut tillers		Time interval (days)	Mean daily % damage
	Pre-treatment	Post-treatment		
10% zinc phosphide/ grease	11.7	34.8	9	2.6
20% zinc phosphide/ grease	7.7	27.4	20	1.0
Reference	10.2	23.5	20	0.7

More than 50% of the rats captured up to 150 m from the study plots were marked with Rhodamine B dye. Trapping at 500 m from the study area yielded almost 20% marked animals. This indicated that many rats contacted the toxicant but did not die.

The toxicant formulation probably was overwhelmed by the extremely heavy rat pressure in this field test. One rat crossing a tile with 3 g of 10% zinc phosphide in grease usually will groom off a lethal dose and die; the delivery system apparently was ineffective for large numbers of rats.

Additional laboratory results indicated that a 50:50 grease to oil formulation was more effective than either grease or oil alone, and that at least 15-20 g per tile would be needed. Alternate toxicants may also be appropriate. If the delivery method can be improved, it could serve as an emergency treatment for preventing losses in mature rice when control was not carried out during the vegetative stages.

Rat Damage in Coffee

Rat damage to coffee was investigated at Kiangan, Ifugao Province. Damage began between October and December when the plants flowered. Branches were chewed, resulting in a high proportion of the plant becoming unproductive. Tracking tile data indicated low rodent activity (4%), but three species, *R. everetti*, *R. exulans*, and *R. r. mindanensis*, comprising 53%, 33%, and 13% of the population, respectively, were identified.

A preliminary test was conducted to reduce damage using an anticoagulant/rice bait on three plots of 800-1,000 trees. Eight bait holders, each containing 150 g of 0.025% warfarin/rice bait were placed in two plots. Farmers checked and replenished the bait station once or twice a week. After 1 month, the treated plots received 12 kg of bait. The results will be available in early 1981.

Evaluation of Rat Control Techniques in Experimental Rice Plots (Sayed Ahmed, M.S. Thesis, in progress)

One of the most difficult areas to control rat damage is in experimental farms where a variety of rice crop stages exist throughout the year. The continuous availability of mature grain competes with grain-based rodenticide baits. Valuable research data, time, and money are lost to rats, which prefer the standing crop over the bait. Many control methods, including deep trenches filled with water, saturation baiting, barriers, and burrow gassing have been tried, but not compared simultaneously.

During 1980, field studies were conducted at the International Rice Research Institute (IRRI) in the rice research farms. Ten experimental plots planted to high-yielding varieties (HYV's) were selected from the IRRI farm area. Four control methods were tested: (1) sustained baiting with a chronic anticoagulant; (2) anticoagulant pulse baiting; (3) lethal electric fence; and (4) a nonlethal electric fence. A fifth plot served as a reference. Each plot was replicated once in a completely randomized design. Data were obtained on rat activity (measured by tracking tiles) and rat damage (determined by an examination of cut and uncut tillers).

Preliminary results indicated that the lethal electric rat barrier effectively prevented damage (Fig. 8). Rat activity was also lowest in these plots. Reference plots received the highest damage. Final

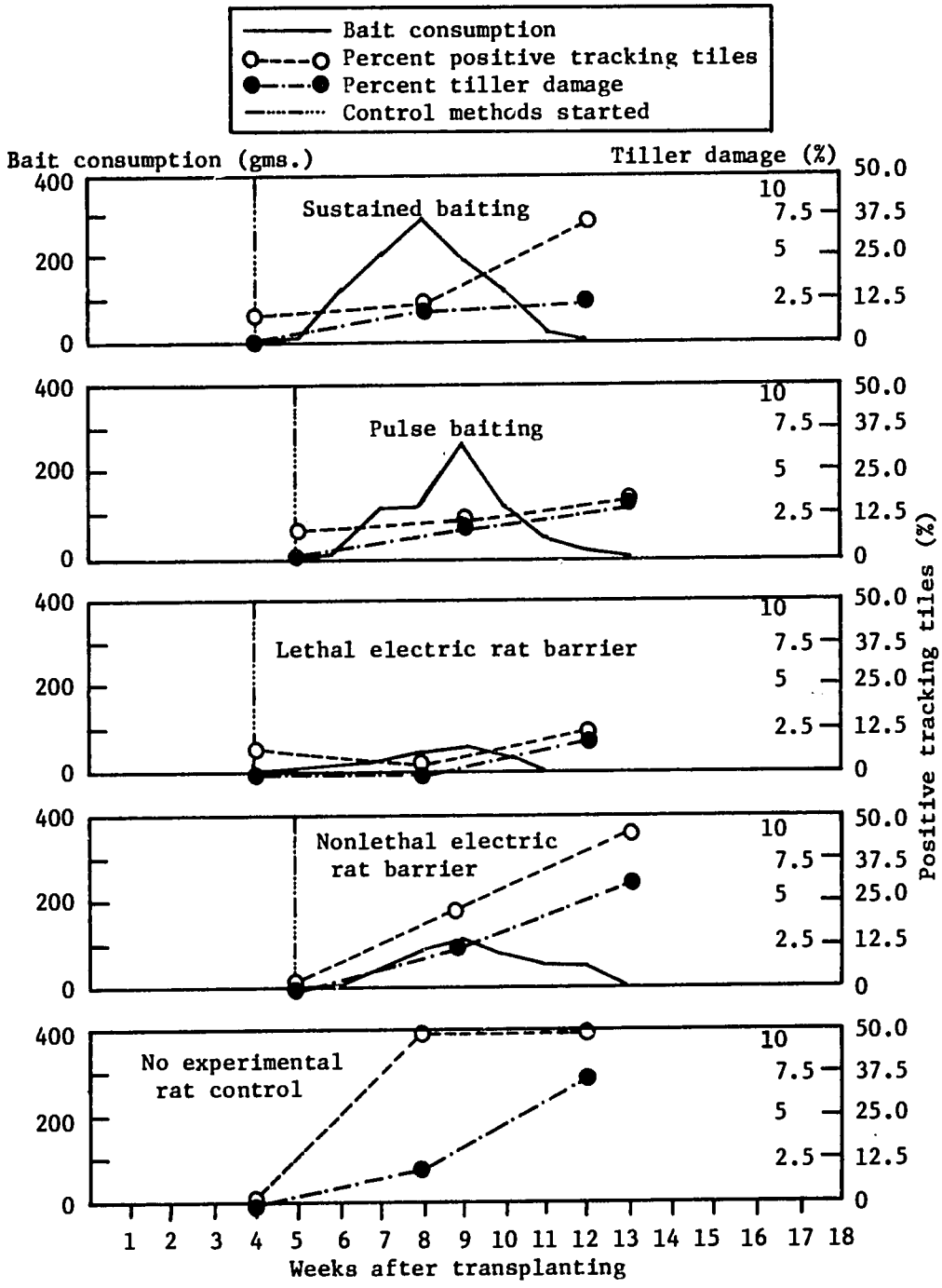

Figure 8. Preliminary results comparing different control methods for reducing rat damage in experimental rice farms in the Philippines. Comparisons based on tracking tile use, tiller damage, and bait consumption by rats in the 1980 wet season (17 October-21 December).

results, including cost comparisons, for all methods will be reported in 1982.

Biology of Rodents in Rice and Wheatfields in Central Punjab, Pakistan (Abstract of M.S. Thesis, A. R. Khokhar)

Small mammals were trapped bimonthly for 14 months in central Punjab. Data on abundance, reproduction, and diet were compared with findings of a previous study in Lower Sind.

Species abundance differed in the two study areas. Bandicota bengalensis was more abundant in Punjab, a result of the availability of a winter cereal crop (wheat), which permitted a second breeding peak. Nesokia indica was much less abundant in Punjab probably due to better weed control along field edges. Millardia meltada also was less abundant. The abundance of Bandicota was reduced after plowing, while Millardia and Mus were little affected.

Reproductive rates were higher and mean adult ages less in Bandicota and Millardia populations in Punjab compared to those in Sind. In Punjab, Mus and Bandicota showed sharp breeding peaks closely linked to the ripening of wheat and rice. Millardia showed pregnancy rates near or exceeding 50% in all but the coldest month, while Suncus bred mostly at the end of the dry season.

Stomach content analysis indicated that rodent damage to wheat was probably more severe than damage to rice since Bandicota and Millardia ate rice less frequently. A damage index, based on stomach contents, indicated that damage to rice in Punjab was only one-third that in Sind.

Demonstration Plots and Cooperative Research Studies

To continue the program of establishing demonstration plots at Regional Crop Protection Centers (RCPC), three projects were initiated during 1980. The overall objective of this program is to disseminate technical information and current recommendations for effective rat control in agricultural crops.

Bicol RCPC/NCPC demonstration project.--This project highlighted rat control in the priority crops. The first project started in October 1980 in coconuts. The coconut project contains two treated and one reference plot. The treated plots were crown-baited with only 10% of the trees being baited. Baiting was done once a month with 150 g of chronic poison and a bait carrier. Monthly counts have been made of dropped nuts (classified as undamaged and damaged nuts), rat activity (tracking tiles), and harvested nuts.

Demonstration of sustained baiting in rice.--A cooperative demonstration of sustained baiting in rice was completed with the Regional Crop Protection Center in San Mateo, Isabela Province (Table 19). The Masagana-99 recommendations for rat control in rice

were followed. Five farms were selected in both the treated (5 ha) and reference areas (4 ha). All participants belonged to a local farmers' association and employed similar agricultural practices except for rat control techniques. R. r. mindanensis and R. exulans were present in the study area. Baiting in the treated farms began in September and ended in November. Rat activity was determined by tracking tiles.

Table 19. Comparison of rat damage in treated and reference plots of rice at San Mateo.

Month	No. bait holders	Amount of bait (kg)	% damage	
			Treated	Reference
September	16	2.4	20.0	17.3
October	72	21.6	9.3	28.0
November	72	10.8	4.0	28.0

Damage decreased from 20 to 4% in the treated farms and increased from 17.3 to 28% in the reference farms (Table 19). Yield differences between the treated and reference farms were 120 vs. 67 cavans/ha. However, typhoon Aring hit the study area near harvest time and affected the reference farms more than the treated farms. Much of the rat damage in the reference farms occurred at mid-crop stage. At harvest, damage was 1.9% in the reference and 0.2% in the treated farms. The farmers in the cooperative put aside 17 cavans of palay for bait material for the next cropping season when the entire area will be baited.

Evaluation of Baiting Intensity for Rat Damage Control in Coconut, Bagabag, Nueva Viscaya

Crown baiting was compared to ground baiting for controlling rat damage to coconuts. Different baiting rates were evaluated in four plots: Plot I (reference), Plot II (1 in 20 trees baited), Plot III (1 in 6.25 trees baited), and Plot IV (1 in 40 trees baited).

Excellent control was observed throughout the year in all treated plots compared to the heavily damaged reference plot (Fig. 9). Despite periodic increases in rat activity at the ground level, the sparsely baited plots (II and IV) prevented significant damage from occurring in the crown. Rat activity, determined by percent tracking tiles marked, was similar throughout the year (Fig. 10).

The fact that sparsely baited plots resulted in good long-term control of rat damage to coconut indicates that it is not necessary to kill all rats in a homogeneous coconut stand--just those entering the crown. However, sparse baiting methods may not always be appropriate, as during flooding or harvesting of adjacent cropland when

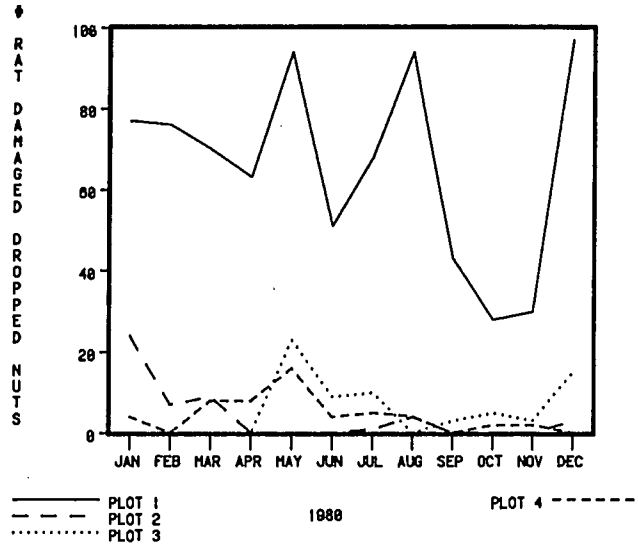

Figure 9. Number of rat-damaged nuts/plot/month in one reference plot (I) and three treatment plots (II, III, IV) at Bagabag, Nueva Viscaya. Five percent of the trees in Plot II were baited, 16% in Plot III, and 2-1/2% in Plot IV.

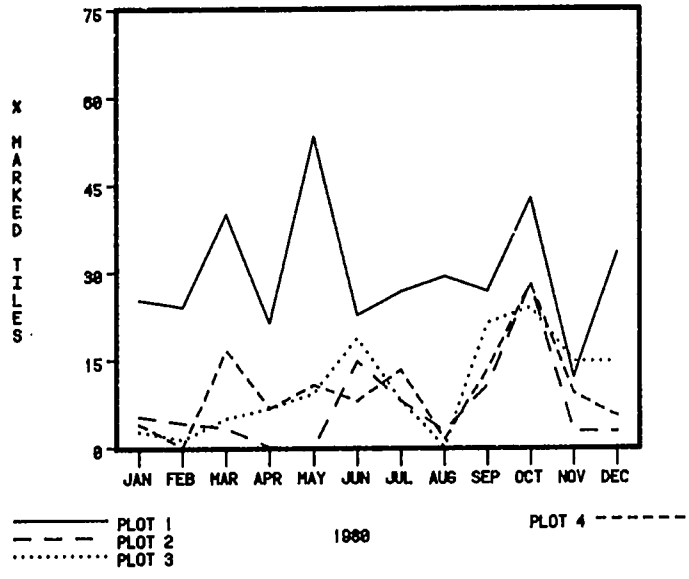

Figure 10. Rat activity, based on the percentage of tracking tiles that were marked in each plot at Bagabag, Nueva Viscaya. Tiles were monitored 3 nights each month.

large numbers of rats could immigrate into coconuts and overwhelm the available bait. Significant damage at these times could eliminate several months of damage reduction gains. The current one in four (25%) baiting rate recommendation can be reduced.

Evaluation of Rat Damage Control in Coconuts Using Moderate Baiting Intensity in Calauan, Laguna

Because of the promising results of the crown baiting study during 1979 in Bagabag, a lower treatment level was evaluated during 1980 near Calauan in Laguna Province. The Bagabag study indicated that a 1:20 ratio can reduce damage but may fail during periods of high immigration of surrounding rats or increased use of coconut for food when adjacent crops are harvested. At Calauan, two treatment plots were established to evaluate lower baiting levels and one plot served as reference. A 1:10 level (one crown baited for every ten trees) was felt to be the optimum level to control rats with the least amount of labor and material cost. One plot (Plot I) was treated at a 1:10 ratio throughout the study. The second plot (Plot II) was initially baited at a 1:6 ratio for 3 months, and at a 1:10 ratio thereafter.

The 10% level reduced rat damage in both treatment plots (Fig. 11). From the third month of baiting with 0.025% warfarin in 150 g binlid/treated tree/month, the number of rat-damaged nuts was <5, except for Plot I, which had a 3-fold increase in damaged nuts in September. The reference plot averaged 15-20 damaged nuts/month until September when the owner removed all maturing nuts in the trees. The result was a large increase in damage to the young nuts in November and December and continued high rat activity within Plot III.

Rat activity (Fig. 12) generally decreased in all plots at the onset of the dry season and increased as the wet season started in May. The reference plot consistently has shown higher rat activity throughout the study.

The 10% baiting rate has provided good control. Damage increased in Plot I during September. This plot was adjacent to ricefields from which rats probably immigrated. The bait may also have spoiled since September is the peak of the wet season. The study will continue for another year to monitor long-term control potentials.

Comparison of Ground Baiting and Trunk Baiting for Rat Damage Control in Coconut at Calauan, Laguna--a Training Exercise

In connection with a training course "Rodent Control in Coconut," two areas were selected for the participants to visit and conduct a study comparing ground and trunk baiting. The ground-baited plot was 1 ha with 160 coconut trees of mixed ages and heights. The trunk-baited plot was 0.65 ha with 100 coconut trees and adjacent to ricefields.

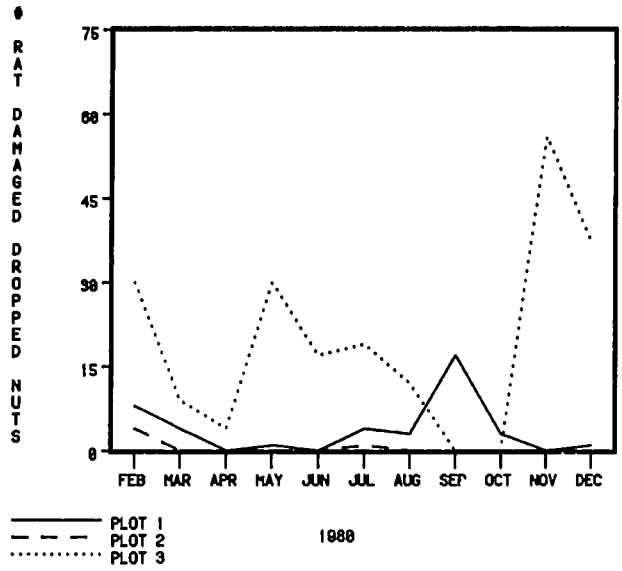

Figure 11. Number of rat-damaged nuts/plot/month in two treatment plots (Plot I and II) and one reference plot (Plot III) during 1980 at Calauan, Laguna Province. Ten percent of the coconut trees were crown-baited in the treatment plots.

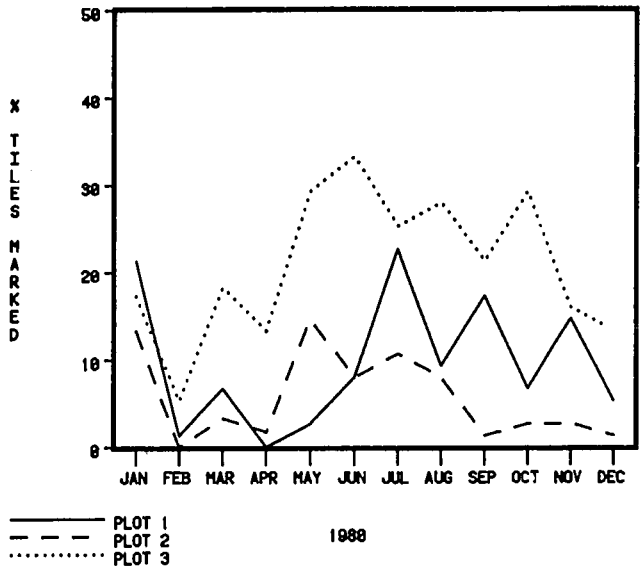

Figure 12. Rat activity, based on the percentage of tracking tiles that were marked in each plot at Calauan, Laguna Province. Tiles were monitored on 3 nights each month.

Eight evenly distributed bait points were selected in each plot. Bamboo tube bait holders were used in the ground-baited plot and coconut husk bait holders were nailed to the trunk about 2 m above ground level in the trunk-baited plot. Once a week, 150 g of 0.025% warfarin mixed with rice shorts was put in the bait holders. Monthly records of dropped nuts (scored as damaged or undamaged), and rat activity (determined by tracking tiles) were kept during the 3-month training course and for additional 2 months thereafter.

Pretreatment damage assessment indicated high damage of 68-74% in both plots. Rat activity also was high, averaging 36 and 24%, respectively (Table 20). Rat damage remained high in the ground-baited plot but was reduced in the trunk-baited plot; rat activity declined in both plots.

Table 20. A comparison of ground- and trunk-baited coconut plots for reducing rat damage to maturing nuts in Calauan, Laguna, Philippines.

Baiting methods and evaluation parameters	Months (1980)					
	Jul	Aug	Sep	Oct	Nov	Dec
Ground-baited plot						
Total nuts dropped	164	156	118	91	120	133
% rat activity index	36.0	30.7	18.7	10.7	20.0	13.3
Trunk-baited plot						
Total nuts dropped	-	70	15	3	8	13
% rat activity index	-	24.0	10.7	6.7	16.0	8.0

Technical Assistance and Extension

Technical assistance was provided to seven of the twelve Regional Crop Protection Centers on vertebrate pest control problems and needs. This assistance is summarized in Table 21.

Cooperation with National and International Organizations

In 1980, project personnel participated in training 71 farmers and farm leaders in methods to control rats in agricultural crops. Technical training of 2-3 months was given to professional research personnel involved in rodent control in coconut in the Comoro Islands and the Republic of Maldives (Table 22).

Table 21. Crop protection extension during 1980.

RCPC	Location	Pest	Crop
VI	Iloilo City	rats	rice
VIII	Abuyog, Leyte	rats	coconut
		birds	rice
X	Malaybalay, Bukidnon	rats	corn
II	San Mateo, Isabela	rats	rice
IV	Los Baños, Laguna	rats	corn
V	Pili, Camarines Sur	rats	corn, coconut
XI	Davao City	rats	rice

Table 22. Summary of Vertebrate Pest Control training in the Philippines during 1980.

Sponsoring agency	No. individuals	Profession	Country	Length of training	Total man-days
World Bank	1	Research	Comoro Islands	2 months	40
	1	Research	United States	2 months	40
FAO	1	Research	Maldive Islands	3 months	60
Philippine Coconut Authority	1	Research	Philippines	3 months	60
International Institute for Rural Reconstruction (IIRR)	30	Farm leader	Philippines	1 day	30
	41	Farmer	Philippines	1 day	41

Personnel and Training

Eight people, including five international students, were enrolled at the University of the Philippines at Los Baños (UPLB) for graduate level training in various aspects of vertebrate pest management. One Filipino attended UPLB, and two others continued their graduate studies at Bowling Green University, Bowling Green, Ohio.

In addition to students enrolled in M.S. and Ph.D. programs, a 10-month diploma program was established in November 1980. Seventeen graduate scholars were funded by a USAID Training Grant through the National Crop Protection Center, College of Agriculture, University of the Philippines at Los Baños.

CARIBBEAN

To address the problem of vertebrate pest damage to agriculture in the Caribbean Region, a regional project was established to serve the needs of Haiti, the Dominican Republic, and other regional countries with special emphasis placed on assisting traditional farmers. The project officially began on 11 May with G. Clay Mitchell's arrival in Port-au-Prince, Haiti, the project's headquarters. Plans for construction of laboratory and office facilities were completed and counterpart positions were filled. On several occasions counterpart personnel of both Haiti and the Dominican Republic have worked together. Fieldwork was begun to determine major farming areas and crop phenology patterns, and to identify bird and rodent pests.

Vertebrate Pests, Crops, and Damage

The main vertebrate pests in Hispaniola are *Rattus rattus*, *R. norvegicus* and the Village Weaver or Madame Saga (*Ploceus cucullatus*), originally introduced from West Africa. Woodpeckers (*Melanerpes striatus*) also damage citrus fruit and cacao in the Dominican Republic. Cropping phenologies have been prepared for the region (Tables 23, 24, and 25) to facilitate this work.

Agriculture in Haiti occurs in both valley (sea level to 300 m) and mountain (above 300 m) zones. The main crops susceptible to vertebrate pest damage in Haiti are rice, corn, and sorghum. The Dominican Republic is divided into seven agricultural divisions. The main vulnerable crops are rice, corn, and hybrid sorghum.

Research Activities for 1981

Because the Caribbean program is a joint venture between Haiti and the Dominican Republic, research priorities have been selected in each country to avoid duplication. Immediate concerns in Haiti include (1) assessing bird and rodent damage to several crops, (2) determining the potential of using miniature radios to study movements of village weavers, (3) evaluating methods of trapping village weavers, and (4) undertaking preliminary investigations of the effectiveness of the sustained baiting techniques (originally developed in the Philippine project) to reduce rodent losses to corn and rice.

Research objectives in the Dominican Republic center around (1) assessing bird damage to ripening cereals, (2) evaluating damage to citrus and cacao by woodpeckers, and (3) evaluating traps for capturing village weavers.

Personnel and Training

Tomas Vargas M. and Manuel Gonzalez from the Dominican Republic received 2 weeks of training at the Denver Wildlife Research Center during August 1980.

Jean-Paul Samedy of Haiti and project counterparts of the Dominican Republic learn radio-tracking techniques which may be useful for monitoring the movements of village weavers in Hispaniola.

Table 23. Periods of growth (---) and maturation (——) for agricultural crops in the valley zones (Region I) of Haiti.

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Corn			---	---	---	——	——	——				
Millet (local)	——					---	---	---	---	---	---	---
Millet (hybrid)			---	---	---	——						
Rice	——	---	---	---	---	——		---	---	---	---	——
Sweet potatoes	——		---	---	---	——			---	---	---	——
Sugarcane	——	——	——	——	——							——
Beans	——	——									---	---
Cotton	——					---	---	---	---	---	---	——

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Table 24. Periods of growth (---) and maturation (——) for agricultural crops in the mountain zones (Region II) of Haiti.*

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Corn		---	---	---	---	---	——	——	——			
Millet (local)	——							---	---	---	---	---
Potatoes	——	——	---			---	---	---	---	---	---	---
Coffee	——	——						——	——	——	——	——
Beans	---	——	---	---	——	——	---	---	---	——	---	---
Sweet Potatoes		---	---	---	---	---	——					
Casava	——		---	---	---	---	---	---	---	---	——	——

* No irrigation in the mountain zones.

Table 25. Periods of planting, growth (---), and maturation (——) for rice and corn in the Dominican Republic.

Region		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North	rice	——	——	——			---	---	---	---	---	---	——
	rice		---	---	---	——	——	——					
	corn	——	——	——	——			---	---	---	---	---	---
Northeast	rice	——						---	---	---	---	---	——
	rice	---	---	---	---	---	---	——	——				
	corn			---	---	---	---	——	——	——			
	corn								---	---	---	——	——
Northwest	rice	---	---	---	---	——	——	——	——	——	——	——	——
	corn			---	---	---	---	——	——	——			
	corn							---	---	---	---	——	——
Central	rice	——				---	---	---	---	---	---	——	——
	corn				---	---	---	---	——	——	——		
South	rice	---	---	——	——	——	——	——		---	---	---	---
	corn	——	——	——	——	——	——	——	---	---	---	---	---
Southwest	rice	——	——	——		---	---	---	---	---	---	——	——
	corn	——						---	---	---	---	——	——
East	rice			---	---	---	---	---	——	——	——	——	——
	rice				---	---	---	---	——	——			
	corn	——						---	---	---	---	——	——

Red-billed quelea being tested for sensitivity to toxicants applied to nesting materials.

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Nest Material as a Means of Delivering Avicides

Aerial spraying of nest sites with avicides (fenthion or parathion) is one of the most frequently used methods of controlling quelea nesting colonies in Africa. Another possible method of applying avicides which is being investigated, uses the nest weaving behavior of the bird to orally or dermally deliver a toxic chemical via treated nesting material. This method requires less toxicant and allows for daytime application.

The objectives of the investigation are to demonstrate that fatal dosages of selected toxicants (fenthion, parathion, and Dasanit) can be delivered to caged quelea via nest material, and to evaluate the efficacy of the method under aviary conditions. Tests involve presenting toxicant-treated nest material to the quelea pairs, observing changes in their weaving patterns at different toxicant levels, and making mortality assessments at 1-, 2-, 4-, and 24-hour postexposure intervals.

With undiluted levels of the avicides (~180-190 mg/strand of nest material), quelea were repelled from weaving the material. Those birds that did contact the material with their feet, died within 15-30 min. The three avicides performed in a manner similar to roost or perching-contact toxicants when used at full strength. Contact with one foot appeared to produce sufficient dermal absorption to be lethal to quelea.

With both fenthion and parathion, little or no mortality was observed at levels below 0.8% weight of chemical/weight of string (w/w) active toxicant on the nest material (~0.04-0.07 mg/strand). Dasanit, however, produced high mortality in males at levels as low as 0.05% w/w (~0.01 mg/strand). Mortality observed in male-female quelea pairs tested over a 5-log unit range of Dasanit concentrations is given in Table 26.

Table 26. Lethal effects of Dasanit when applied to five 12.7-cm strands of nest material and presented to quelea pairs for a 2-hour exposure period.

% concn	Dilution level with acetone	Male mortality	Female mortality	Total mortality
100.0	Undiluted	5:6	2:6	7:12
3.2	1:31	6:9	3:9	9:18
0.8	1:127	8:9	5:9	13:18
0.2	1:510	6:9	2:9	8:18
0.05	1:2,040	7:9	0:9	7:18
0.0125	1:8,160	2:9	1:9	3:18
0.0031	1:32,640	0:7	0:7	0:14

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Two additional levels of Dasanit (0.39% and 1.25%) will be tested to delineate the optimal levels for use in an aviary cage test with 20-30 pairs of quelea. Optimal range currently is estimated as 0.2-3.2%; mortality declines at levels above and below this range.

Importation of Lesser Bandicoot Rats (*B. bengalensis*)

Thirty-three lesser bandicoot rats were imported to DWRC from Dacca, Bangladesh in September 1980. They were placed in individual laboratory cages and then given daily maintenance for 30 days in a secured animal colony. Three male-female pairs were set up to sample breeding activity and aggressiveness. One of the pairings produced a litter of eight. Construction of facilities to breed lesser bandicoot rats for research at DWRC is underway.

Drug-induced Taste Aversion in Ricefield Rats (*R. r. mindanensis*): Factors Affecting Drug Effectiveness and Feasibility of Use for Reducing Crop Damage

Conditioned taste aversion occurs when a rat is poisoned with certain drugs shortly after tasting a novel-flavored substance. Taste aversion is characterized by a sharp reduction in preference for similarly flavored food items. Conditioned taste aversion is a method which may be useful in controlling rat damage to agriculture.

To assess the feasibility of producing conditioned taste aversion, two groups of 10 rats were required to obtain their daily feed (California brown rice) in 2-hour periods for 14 days. During the next 2 days, one group was offered a choice between ground rice treated with 5.0% corn oil, 0.3% sodium saccharin, and 3.0% lithium chloride (LiCl-drug). The other group was given ground rice containing these flavors with 3.0% sodium chloride (NaCl-control). Following a 1-day recovery period in which all rats were given untreated ground rice, preference tests between ground rice and saccharin-oil flavored rice were conducted for the next 14 days. An aversion index,

$$AI = 1.0 - \frac{\text{amount of saccharin-treated rice consumed}}{\text{total amount of food consumed}}$$

was calculated for each rat each day. All LiCl-dosed rats showed strong aversion (AI $\geq$0.90) for 6 days. Rats given NaCl showed no aversion (AI $\leq$0.40), indicating preference for saccharin-flavored rice. Mean aversion indices for the 14 test days are shown in Fig. 13.

Similar procedures were used to compare conditioned taste aversion to saccharin-flavored ground rice in food-deprived and nondeprived rats. Throughout the 2-week preference-test period, the nondeprived rats exhibited slightly greater conditioned taste aversion than the

A ricefield rat (R. r. mindanensis) is tested for aversion response after baiting with LiCl-treated rice.

deprived rats. Mean aversion indices for 2-hour vs. 22-hour food-deprived rats are shown in Fig. 14.

To assess the possibility of transferring conditioned taste aversion among different foods, green rice plant material was substituted for ground rice in the preference test phases after rats had been either exposed to LiCl- or NaCl-treated rice flavored with oil, saccharin, and almond extract. The rats generally failed to exhibit taste aversion to green plant material treated with these flavoring agents, perhaps due to texture differences.

To evaluate this possibility, two groups of eight rats were dosed with either LiCl or NaCl (control). Half of the LiCl-treated rats received the chemical in either whole-grain or ground rice bait. The control rats received NaCl in either ground or whole rice baits. After a 2-day recovery period, each rat was presented with two food cups containing either whole rice that was untreated or whole rice treated with saccharin, corn oil, or almond extract. The texture change from ground to whole rice had no effect on the conditioned taste aversion response (Table 27). Additional work to explain the taste aversion transfer from grain baits to the growing plants is needed if the method is to be useful for reducing rodent damage to field crops.

Simulated Burrow System for Laboratory Evaluation of Rodent Fumigants

Toxic gases have been employed as vertebrate pest control agents for many years. Methyl bromide, calcium cyanide, chloropicrin, aluminum phosphide, and carbon monoxide are the more commonly used and well-known fumigants. Although efficacy under field conditions is the ultimate goal, relatively little efficacy data under laboratory conditions are available for fumigants. Unfortunately, no specific laboratory testing standards or methods have been established.

A burrow system which simulates that of wild rodents was constructed to permit obtaining laboratory data on initial efficacy, comparative evaluations of different formulations or materials, direct observation of animals exposed to the agent, precise measurement of fumigant concentration at different points within the system over time, ease of application, and immediate access to target animals for examination or use in secondary hazard evaluations.

The physical dimensions and characteristics (number of openings, branches, chambers) of the burrow system are based on average measurements obtained from excavating 20 lesser bandicoot rat (*B. bengalensis*) burrows in Bangladesh. The simulated rodent burrow system was constructed primarily of 7.5-cm (i.d.) PVC pipe. A 1.2-m section of copper pipe is used at the point where the fumigants are introduced. Nests or storage chambers are made with 3.8-L metal containers. Sections of clear plastic pipe and windows were incorporated to observe test animals. Test animals could be held at 11

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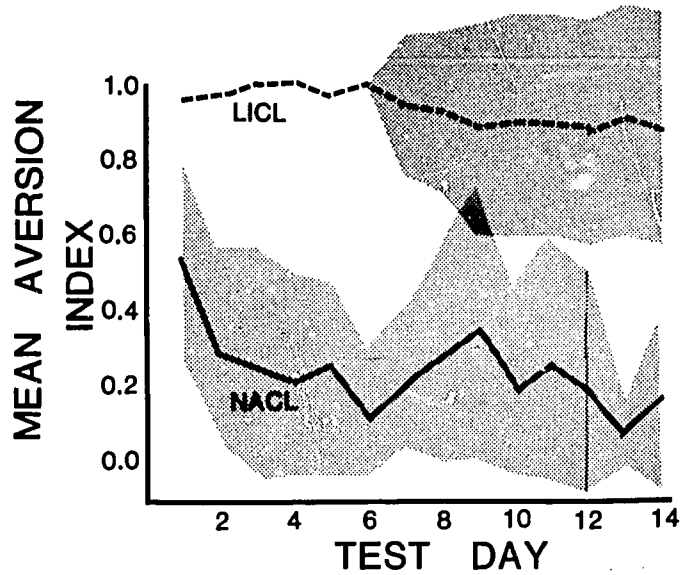

Figure 13. Relative aversion levels produced by free ingestion of LiCl-treated vs. NaCl-treated saccharin- and oil-flavored ground rice in R. r. mindanensis.

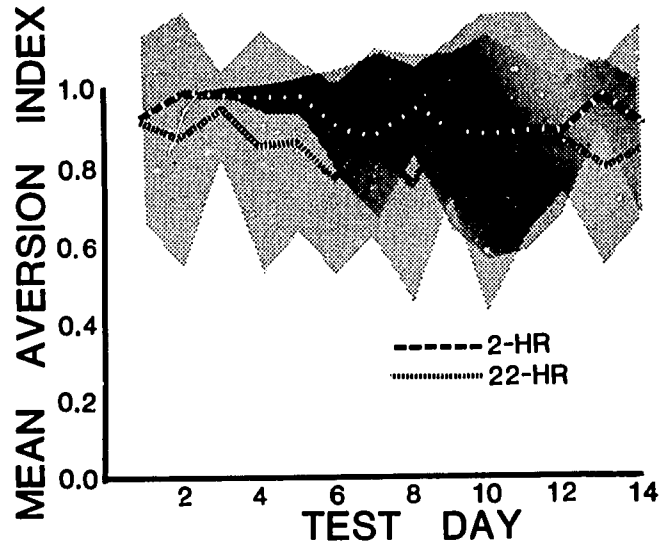

Figure 14. Relative aversion produced by free ingestion of LiCl-treated ground rice. The 2-hour group was dosed and tested with 2-hour food access periods and the 22-hour group was dosed and tested with 22-hour food access periods.

Table 27. Aversion indices* for rats given either a texture change or no texture change between the baiting and preference test phases.

	Test group			
	Texture change (ground rice bait changed to whole-grain rice during preference test)		No texture change (whole-grain rice used for both baiting and preference test phases)	
Day	LiCl	NaCl	LiCl	NaCl
1	.904 ± .029	.639 ± .243	.934 ± .017	.221 ± .275
2	.938 ± .019	.569 ± .307	.949 ± .029	.037 ± .032
3	.951 ± .001	.432 ± .299	.915 ± .091	.026 ± .022
4	.966 ± .015	.347 ± .213	.958 ± .033	.010 ± .009
5	.980 ± .011	.147 ± .081	.980 ± .019	.011 ± .092
6	.975 ± .011	.164 ± .114	.948 ± .068	.050 ± .056
7	.979 ± .014	.087 ± .093	.888 ± .160	.010 ± .008
8	.996 ± .006	.159 ± .142	.798 ± .336	.070 ± .123
9	.987 ± .011	.167 ± .198	.853 ± .215	.008 ± .005
10	.991 ± .010	.150 ± .142	.812 ± .337	.005 ± .006
11	.990 ± .009	.153 ± .136	.725 ± .400	.008 ± .006
12	.995 ± .014	.080 ± .100	.737 ± .378	.005 ± .009
13	.997 ± .005	.155 ± .219	.776 ± .348	.003 ± .005
14	.983 ± .010	.170 ± .095	.735 ± .352	.066 ± .098
15	.962 ± .045	.117 ± .112	.626 ± .409	.013 ± .018
Mean dosage received (mg/kg)	93.3 ± 58.1	635.9 ± 257.7	137.2 ± 87.9	1210.0 ± 224.6

* AI = 1 -(amount of flavored rice eaten/total amount of food consumed).

different locations, and simple modifications will expand this capacity. Burrow entrances could be opened or closed during testing and animals could be restrained at the observation points or allowed free movement. The configuration of the system could be easily and quickly changed to simulate burrows of other species. Measurements and samples of oxygen or toxic gases could be taken through self-sealing ports anywhere along the system. The total volume of the simulated rat burrow system is 0.2 m^3. A comparison of several characteristics of the actual and simulated rat burrows is given in Table 28.

Table 28. Comparison of actual and simulated burrow system of lesser bandicoot rats.

Burrow system characteristics	Lesser bandicoot rat ($\bar{x}$ of 20 burrows)	Simulated burrow system
No. entrances	6.4	6
Plugged (closed) entrances	3.9	0-6
Total length	40.2 m	40.2 m
Burrow diameter	76.9 mm	76.2 mm
Average depth	16.7 cm	NA
No. branches	27.6	28
$\bar{x}$ distance between branches	1.1 m	1.2 m
No. dead ends	4.2	4
No. storage chambers	2.5	4
No. nest chambers	1.5	4

Laboratory Evaluations of Rodent Fumigants

Testing and evaluating rodent control fumigants in the simulated burrow system is continuing. Fourteen formulations or concentrations involving eight fumigants have been tested on 258 animals in 86 trials. In each trial, three albino rats were exposed to fumigants at distances of 3.3, 6.0, or 10.0 m from the material's point of entry. Results of these trials are summarized in Table 29.

Field Evaluation of Pyrotechnic Rodent Fumigants

Rodent control methods such as trapping or baiting can be ineffective or uneconomical under certain conditions. An abundant, readily accessible preferred food source will render baits practically useless because the animals will utilize the natural food. Very high populations make trapping as a control method inappropriate. These conditions often exist in and around grain storage areas, livestock installations, or in fields of mature crops. To determine the efficacy of an experimental fumigant cartridge, a limited field trial was conducted at a cattle feedlot where a large rodent population and abundant food existed.

Table 29. Fumigant trials in a simulated burrow system with male albino rats. Values given are averages from a series of tests in which rats were positioned at different distances from the entry point of candidate fumigants.

Material	Distance from fumigant source					
	3.3 m		6.0 m		10.0 m	
	Rat wt ($\bar{x}$) (g)	Death time ($\bar{x}$) (min)	Rat wt ($\bar{x}$) (g)	Death time ($\bar{x}$) (min)	Rat wt ($\bar{x}$) (g)	Death time ($\bar{x}$) (min)
$NaNO_3$ (65%), C (35%)	218	24	220	63	242	115
$NaNO_3$ (50%), C (50%)	259	31	264	114	248	>263*
Fert. #1 (65%), C (35%)	358	56	365	139	362	>235
Fert. #1 (50%), C (50%)	300	81	295	140	235	__**
Fert. #2 (65%), C (35%)	352	23	340	130	346	150
Fert. #2 (50%), C (50%)	298	71	338	>230	350	>208
$NaNO_3$ (65%), C (30%), oil (5%)	191	30	194	99	195	159
$NaNO_3$ (55%), C (35%), oil (10%)	249	21	273	116	297	158
$NaNO_3$ (50%), C (35%), oil (15%)	248	23	227	550	__**	__**
$NaNO_3$ (45%), C (35%), oil (20%)	264	20	301	>40	265	>263
Phostoxin tablets (AlP)	244	>297	242	>345	__**	__**
Mg_3P_2 (12 tablets)	286	138	231	>289	291	>267

* > indicates there were survivors or overnight deaths for which no times are available.

** __ indicates all test animals survived and/or no weights taken.

Ten test sites were selected at different points within the feedlot and rodent activity was measured for 3 days using the closed-hole technique. Following a count of active burrows on the 3rd day the test sites were fumigated with the experimental two-ingredient fumigant cartridge. Activity counts were repeated for 3 more consecutive days after fumigation (Table 30).

Table 30. Counts of active burrows before and after treatment with fumigant cartridges.

Test sites	Pretreatment (day) 1st	2nd	3rd	$\bar{x}$	Posttreatment (day) 1st	2nd	3rd	$\bar{x}$	% reduction of active burrows
1	26	34	22	27	0	2	2	1	95
2	8	14	24	15	1	2	2	2	89
3	18	13	24	18	1	1	2	1	93
4	53	51	57	54	11	21	21	18	67
5	44	24	33	34	8	10	7	8	75
6	5	8	7	7	4	5	4	4	35
7	38	29	15	27	3	6	8	6	79
8	20	18	24	21	2	4	3	3	85
9	86	59	64	70	26	19	15	20	71
10	182	206	249	212	52	41	46	46	78
Total	480	456	519	485	108	111	110	109	77

The results suggest that fumigant cartridges can reduce rodent populations at cattle feedlots or in similar situations where baits and traps might be inappropriate. Efficiency, operational safety, low hazard potential to nontarget animals, versatility, ease of handling, and reasonable cost ($0.06/cartridge in this case) are major advantages of the technique. The fumigant cartridge is being tested in the Philippines and Bangladesh.

Toxicity of Zinc Phosphide Formulated in Grease to Ricefield Rats (*R. r. mindanensis*)

A formulation containing 94% multipurpose grease, 5% zinc phosphide, and 1% Rhodamine B was administered by gavage, topically to the feet, and topically to the abdomen of ricefield rats. Groups of five male rats were each given about 0.6 ml of the formulation and then returned to individual cages and observed for 7 days (Table 31). No statistical difference occurred in mortality among the three groups of rats. An increased concentration of zinc phosphide might improve mortality in topical applications.

Table 31. Toxicity of 5% zinc phosphide formulation to male ricefield rats.

Application method	Mean amount (g) and range of grease-zinc phosphide formulation applied	Mean dose (mg/kg) and range of zinc phosphide	Mortality rate of rats
Gavage	0.53 (0.45-0.61)	106 (71-134)	5/5
Topical feet	0.59 (0.49-0.72)	130 (100-186)	4/5
Topical abdomen	0.62 (0.49-0.66)	126 (101-148)	3/5

Toxicity of Commercial Rodenticides to Agricultural Rodents in Developing Countries

Toxicity work with commercial rodenticides is continuing and bioassays with Norbormide, 1081 (fluoroacetamide), zinc phosphide, and DRC 4575 have been completed with the Nile rat (*Arvicanthis niloticus*) (Table 32). No deaths were recorded using Norbormide, attesting to its selective toxicity to *Rattus* spp. The sole survivor from the 1081 tests continued to avoid untreated bait 1 week after exposure to treated bait, indicating extreme bait shyness. All rats exposed to zinc phosphide and DRC 4575 died.

Silicon Dioxide Gels for Wildlife Management Applications

Most rat species are meticulous groomers and remove foreign matter, such as dust and grease, from the pelage. Rodenticidal dust formulations are available, but have not proven suitable for use outdoors or in moist environments. A variety of attempts have been made to prepare suitable formulations for such situations. Most of these have used petroleum-based materials. After contact with the materials, rodents ingest the rodenticide during natural grooming.

The purpose of this study was to examine nonaqueous gels for rodenticide applications. Twenty starches, glutens, carrageenins, gums, and silicon powders were blended with additives and tested for their feasibility for field application.

Gums, carrageenins and Avicel products performed best as thickeners for suspending chemicals for spray application. Viscosity and tack values for silica-corn oil gels tested are presented in Table 33. Keltrol Xanthon gums appeared most suitable for field use.

Tests also revealed that amorphous silicon dioxide powders and gels may be useful as rodenticide carriers and may have many other management applications, such as carriers for attractants or repellents. The gels might be applied by means of a tracking formulation or by rubbing posts placed near burrow entrances.

Table 32. Chemical bioassays of rodenticides with Nile rats (*Arvicanthis niloticus*).

Chemical Rats	Concn (%)	Avg (g) amount and range of treated bait eaten	Avg (mg/kg) amount and range of chemical eaten	Mortality rate of rats
Norbormide				
Males	1	4.0 (3.2-4.9)	284 (231-302)	0/5
Females	1	4.7 (3.9-5.9)	334 (276-422)	0/5
1081				
Males	2	2.9 (0.2-5.5)	337 (22-660)	4/5
Females	2	1.9 (1.0-3.0)	257 (132-356)	5/5
Zinc phosphide				
Males	1	3.1 (2.7-3.7)	151 (141-171)	5/5
Females	1	1.7 (1.1-2.4)	143 (64-191)	5/5
DRC 4575				
Males	0.5	2.3 (1.1-3.7)	77 (35-140)	5/5
Females	0.5	1.4 (0.5-2.6)	73 (14-138)	5/5

Vegetable oil gels from the hydrophobic silicon dioxide remain effective when subjected to moderate to high rainfall. This is of particular importance when considering bait spoilage and product longevity during field use.

Comparing Methods for Analyzing Tannin in Sorghum

Some sorghum varieties are less susceptible than others to bird damage because they contain tannins. In some of these high-tannin varieties, the tannin activity is present only in the milk and early dough stages so that the mature grain is highly nutritional (Type II sorghum). The repellency to birds of these sorghum varieties is related to the astringent properties of tannins which decrease during ripening. A biochemical assay method, based on tannin-protein interaction (astringency), was developed to determine and rank varieties which had high tannin content in the immature stages only.

The two assay methods, amylase enzyme inhibition and protein precipitation, were developed and compared; each had particular limitations. The enzyme assay method gave highly variable results (Table 34).

Table 33. Viscosity* and tack** values for silica-corn oil gels as a function of temperature.

Silica product	Temperature (°C) 5° Viscosity	5° Tack	15° Viscosity	15° Tack	25° Viscosity	25° Tack	35° Viscosity	35° Tack	50° Viscosity	50° Tack
Syloid 244	219.0	49.5	255.0	56.2	259.0	44.3	260.0	28.5	262.0	18.7
Zeolex 7	232.5	27.2	266.0	27.5	275.0	35.1	289.0	18.6	290.0	18.0
Zeolex 265	234	30.7	242.0	32.0	260.5	36.1	270.0	20.6	276.0	15.4
Zeolex 23A	233	25.5	270.0	30.2	275.5	18.3	284.0	18.0	286.0	8.0
Zeosyl 110SD	228.5	2.0	260.0	1.5	261.0	0.8	263.0	1.5	268.0	2.2
Zeofree 80	228.0	14.9	259.0	15.0	259.0	15.0	260.0	9.5	260.0	9.0
Hysil T6000	250.0	21.1	255.0	21.5	257.0	21.6	265.0	18.6	270.0	17.1
Silcron G100	221.0	48.1	228.0	41.0	259.0	39.0	262.0	38.0	275.0	37.2
Silcron G100T	229.0	43.9	239.0	40.0	262.0	38.5	270.0	36.0	276.0	36.0
Tullanox 500	249.0	102.5	261.0	179.5	274.0	120.0	278.0	112.0	290.0	107.0

* Viscosity determined by the ASTM D217 method for cone penetration of lubricating greases (mm/10).

** Tack determined by dipping a glass slide 2 cm into candidate gel (mg).

Table 34. Accuracy of the enzyme assay based on % inhibition* by tannins isolated from BR-54 sorghum.

Replications	mg tannin 0.05	0.5	1.0	2.0
1	11.11	64.44	68.89	100.0
2	11.54	67.31	100.0	100.0
3	2.73	100.0	100.0	100.0
$\bar{x} \pm$ SD	8.46 ± 4.97	69.6 ± 6.65	89.6 ± 17.96	100 ± 0

$$* \% \text{ inhibition} = \frac{\text{distilled } H_2O \text{ Control IU/L} - \text{Sample IU/L}}{\text{distilled water Control IU/L}} \times 100$$

The protein precipitation method was acceptable only after the problems of distinguishing interference with nontannin pigments and the inability of some sorghum varieties to precipitate were solved. Because variation among replicates was less (Table 35), the protein precipitation method was preferred over the enzyme inhibition method. The protein precipitation assay offers greater reproducibility and, therefore, will be used in future laboratory evaluations of tannin activity in sorghums. The development of this method should encourage the breeding of additional varieties of Type II sorghums.

This effort to develop assay methods to predict the relationship between bird repellency and nutritional quality in sorghum varieties was conducted through a cooperative arrangement with the Agronomy Department of the University of Arkansas. DWRC has conducted biochemical and repellency testing of sorghum varieties while the University has worked primarily with plant breeding and varietal selection studies.

Table 35. Accuracy of protein precipitation based on spectrophotometric absorption (A^{o}) by tannins isolated from BR-54 sorghum.

Replications	mg tannin 0.075	0.15	0.50	1.0
1	6.0	11.0	36.8	69.6
	5.5	11.0	38.0	74.0
2	5.0	10.8	37.7	73.0
	-	-	35.9	-
3	5.0	11.1	39.0	-
	5.4	9.8	37.2	76.3
4	5.8	12.2	38.9	72.9
	6.0	11.9	34.9	73.9
5	5.7	11.0	34.5	71.0
	5.7	11.4	37.2	70.1
$\bar{x} \pm$ SD	5.57 + 0.377	11.13 + 0.68	37.01 + 1.53	72.6 + 2.24

Evaluating Curb as a Bird Repellent

Curb^{R}, synergized aluminum ammonium sulfate, is a chemical which reportedly affects gustatory, olfactory, and tactile senses of birds and mammals. Ten formulations, provided by the manufacturer (Sphere Laboratories, London), were tested in two-choice preference tests and no-choice tests on individual red-billed quelea (three male and three female) at DWRC laboratories. Curb was formulated at 0.1% w/w as a surface coating on hulled proso millet seed and offered to quelea in a preference test paired with untreated millet. In two-choice tests, quelea ate significantly more untreated than treated food for formulations two through six (Table 36).

In no-choice evaluations, 37 seeds were offered to five birds in each test. No birds ate <50% of the 37 seeds. None of the formulations were considered repellent to quelea in these tests.

Enhancement of Bird Repellency to Methiocarb by Adding Sensory Cues

Enhancement of methiocarb formulations with tactile, visual, and olfactory cues appears to be a promising repellent technique for reducing bird damage. During 1980, the repellency of several naturally occurring plant extracts were evaluated.

Table 36. Mean preference response to 10 formulations of Curb in two-choice tests of individual quelea (three male and three female).

Curb formulation no.	% preference	Probability
1	36.5	0.12
2	36.6	0.02*
3	36.7	0.05*
4	39.0	0.05*
5	31.0	0.005*
6	30.1	0.01*
7	29.4	0.07
8	37.2	0.15
9	34.0	0.11
10	39.5	0.21

* Significant at the probability indicated according to two-tailed paired t-tests.

Candidate extracts were screened using a two-choice test (Table 37). Each candidate was formulated in a 0.5% solid Rhoplex AC-33 suspension and applied to the test food. Candidates were formulated at 0.5% w/v with 0.05% w/v methiocarb. Ten milliliters of the formulation were surface coated on 200 g of hulled proso millet, allowed to dry at room temperature, then held for 60 hours at 43°C in an oven to simulate exposure in arid climates.

Although several plant essential oils were repellent to quelea when coated at 0.1% (w/w) on hulled proso millet, a few candidates offered repellency at lower levels. The most promising spices and plant extracts were tested individually (without methiocarb) at 0.05% concentration (Table 38).

Wild ginger, which had been very effective at the 0.1% concentration in earlier tests, also was repellent at the lower concentration. Oleo of black pepper was the most repellent extract.

The oleoresin of black pepper and a red dye were later combined as sensory cues with methiocarb to try and reduce blackbird damage to sunflowers in South Dakota. Sunflowers are one of the most difficult crops to protect from birds. The oleoresin odor dissipated after 1 day and the particular methiocarb-cue combination was ineffective. Chemicals relying on odor cues seem impractical for field use; cues with contrasting colors to the food source should be evaluated.

Table 37. Mean preference response of quelea (three males and three females) to candidate sensory cue-methiocarb formulations in two-choice tests.*

Sensory cues	% preference**	Significance (P two-tailed paired t-test)
Oak chip extract (Florasynth)	40.2	0.2
Bitter extract (Florasynth)	35.8	0.1
Astringent extract (Florasynth)	45.5	0.2
Curb #5	46.9	0.1
Wattle tannin-methyl anthranilate	31.3	0.04
Cascara	44.0	0.02
Cumin resoleum (McCormick)	13.9	3.2×10^{-4}
Black pepper oleo (McCormick)	2.9	1.9×10^{-4}
Paprika oleo (McCormick)	4.2	4.3×10^{-4}
Ginger oleo (McCormick)	7.4	4.8×10^{-4}
Capsicum oleo (McCormick)	2.7	2.0×10^{-4}
Fenugreek extract (McCormick)	9.0	1.3×10^{-4}

* Surface-coated formulation of 0.0025% methiocarb (w/w), 0.025% candidate cue (w/w), and 0.025% solids (w/w) Rhoplex AC-33 adhesive on hulled proso millet. Only adhesive was applied to control seeds.

** Percent preference $= \frac{\text{treatment consumed}}{\text{treatment and control consumed}} \times 100$

Table 38. Mean preference response to candidate spices and essential oils in two-choice tests on individual red-billed quelea (three males and three females).

Sensory cues	% preference	Significance (P two-tailed paired t-test)
Cumin resoleum	36.3	0.14
Black pepper oleo	5.6	3.00×10^{-4}
Paprika oleo	5.5	4.50×10^{-4}
Paprika oleo*	49.6	0.95
Ginger oleo	33.2	0.03
Capsicum oleo	42.9	0.15
Fenugreek extract	54.1	0.57
Wild ginger oil (rhizome)	16.9	7.50×10^{-4}
Wild ginger oil (plant)	9.3	6.42×10^{-4}
Nutmeg oil	30.2	0.03

* Red dye added at 0.1% (w/w) to both treated and untreated seeds to minimize color differences.

Marking Animals with Microtaggant and Metal Flake Particles

The feasibility of using small, fluorescent, coded plastic particles, called Microtaggants[R], to mark birds has been evaluated for several years (Fig. 15). The goal is to develop a method for uniquely marking birds in individual roosts by aerial sprays. Microtaggant particles contain coded colored layers, making the concept of individual roost marking possible. The technique was tested during December on blackbirds at Las Animas, Colorado.

Another particle marker has potential for mass-marking birds. These markers are small, colored rectangles (440μ x 375μ x 34μ) of metalized polyester film. Many colors are available and the use of an 8-10 power magnifier allows each color to be discriminated. The particles also were tested in the spray formulation with Microtaggants at Las Animas. The Microtaggant-metal flake combination provides a marker that can be seen under ultraviolet light or in daylight.

The metal flake particles were also mixed with ground corn and fed to wild Norway rats in an outdoor colony to evaluate their suitability as a bait marker for mammals. The marker was accepted by the rats, and could be detected in their digestive tracts and fecal

Figure 15. Microtaggant particle viewed on edge. The different layers comprise an identifying code which distinguishes one group of Microtaggants from another. The top (black) layer is ferromagnetic. The next five layers are colored and the bottom layer is fluorescent. The actual thickness is approximately 136μ. The relative size of the particles is demonstrated in the insert where particles have been sprinkled over a centimeter scale.

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Mr. Saeed Suliman, a graduate student from Sudan, measures sorghum bait eaten by Nile rats at the Denver Wildlife Research Center.

pellets. In December, a cooperative field trial was conducted with Ministry of Production personnel in the Comoro Islands, Indian Ocean. Different-colored markers were placed in bait in the crowns of coconut trees and on the ground beneath them. Rats readily found the bait stations and fed both in crowns and on the ground. Marker colors were easily distinguished in the field, greatly simplifying the procedures for this type of study.

A cooperative field study of Microtaggants with FAO (Food and Agriculture Organization of the United Nations) ornothologists was undertaken to mark red-billed quelea in Ethiopia, Africa. The study was to determine local movements and migration patterns of quelea populations. However, only hand spraying equipment was available and it was not possible to mark a sufficiently large umber of birds to recapture them during migration. Mass-marking research is continuing with these materials and with microscopic fluorescent particles which will be tested in Africa in mid-1981.

Bait-intake Patterns of Rats: A Comparative Study of Select Rodenticides

The computerized data-recording system, modified to include a Texas Instrument 820 Printer and a Hazletine 1500 Visual Display Terminal, continued to prove useful for analyzing rat feeding behavior. A study to compare the minute-by-minute feeding patterns among groups of Nile rats (*Arvicanthis niloticus*), cotton rats (*Sigmodon hispidus*), and wild-caught and albino Norway rats (*Rattus norvegicus*) was completed. Rats were fed ground Purina Rat Chow (single-food cup) *ad libitum*. Continuous, 7-day feeding patterns of these species were monitored with groups of eight rats. Average food-intake patterns for each of the groups provided characteristic, yet quite different, species profiles (Fig. 16). Note the peak feeding rates of <0.6 g/min for each species, and the differences in shape of distributions. Contrary to expectations, albino rats ate food at slower rates than the other species; several wild-caught Norway, cotton, and Nile rats showed several large g/min rates of gulping. Detailed statistical analyses and other graphic displays of the feeding data are currently underway.

Production and Design of Wildlife Tracking Transmitters and Receivers

The project continued to produce specialized miniature radio transmitters for use overseas. Of particular interest has been the development and testing of 1.7- to 1.9-g bird transmitters designed to attach to the tail or leg of small passerine birds. Laboratory studies on red-billed quelea have shown that the tail attachment is more practical. Field evaluations of these radios are planned for house sparrows in Colorado and red-billed quelea in Africa during 1981.

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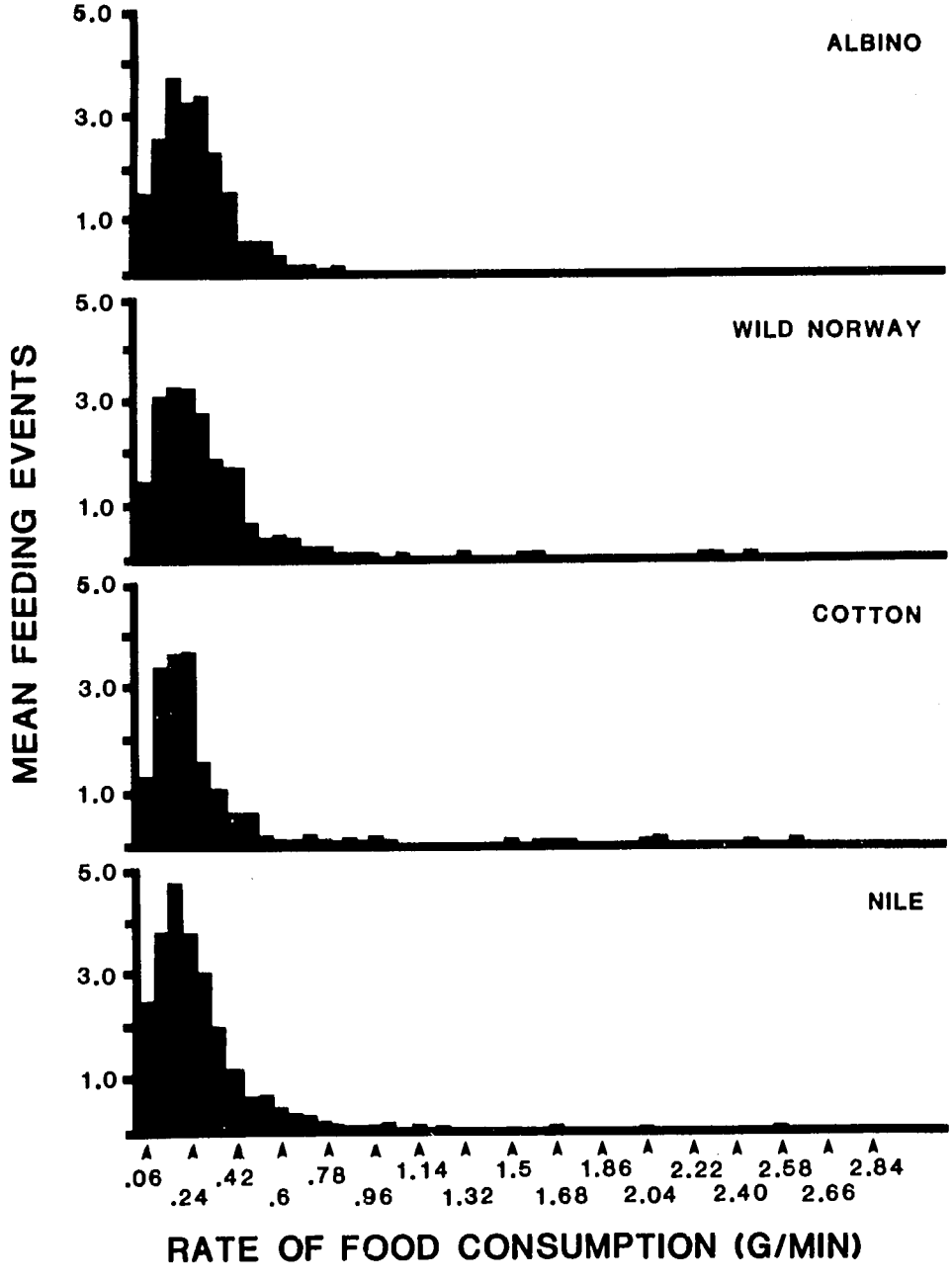

Figure 16. Mean food-intake profiles for separate groups (n = 8/group) of albino, wild-caught Norway, cotton, and Nile rats on Day 7 of the test.

Dr. Gaafer Ahmed El Zorgani, ARC chemist from Sudan, assisted DWRC chemists in developing a technique for analyzing residues of methiocarb.

Testing to improve the encapsulation techniques for wildlife transmitters continued with many types of protective coatings evaluated. Three new compounds have been selected which significantly improve transmitter reliability.

A small mortality transmitter weighing about 14 g with a 90-day battery life was designed and developed for a tail clip attachment to barn owls. These mortality transmitters operate with a motion sensitive switch and a timing circuit. If the motion switch does not reset the timing circuit every hour, the transmitter switches into a mortality mode of radio transmissions. This mortality transmitter could have widespread use in ecological research.

Receiver Design Evaluation for Wildlife Telemetry Systems

A feasibility study for an advanced statistical processing VHF receiver for wildlife telemetry was completed. This hardware development has the unique capability of fully automating wildlife telemetry receiving sites and providing data in a compatible format for computer processing. Additionally, the receiving technique conserves the radio frequency spectrum by allowing more animals to be instrumented on the same frequency without loss of individual identification. The ramifications for this new receiving hardware should impact many programs within the Fish and Wildlife Service.

Analysis of Rice and Plant Samples for Methiocarb Residues

The method most often used to analyze for methiocarb residues involves derivatizing methiocarb and its sulfoxide and sulfone metabolites with a silylating agent, bis(trimethylsilyl)trifluoroacetamide (BSTFA). The derivatives are then quantified by gas chromatography with a flame photometric detector. Another method, in which methiocarb and the carbamate and phenolic metabolites are determined by derivatization with trifluoro-acetic anhydride (TFAA), currently is being investigated. This method appears promising because it uses the sensitivity of electron capture detection and enables simultaneous determination of the primary compound and each of the carbamate and phenolic metabolites.

Several analyses were performed for methiocarb residues on rice seeds and seedlings from Sudan. The rice seeds, which were treated at 0.2% were analyzed by (1) gas chromatography with a thermionic N/P detector, (2) high performance liquid chromatography, and (3) measurement of the trifluoroacetylated derivative of methiocarb by gas chromatography with an electron capture detector. Methiocarb residues ranged from <1 ppm to 12 ppm in the rice seedling samples (Table 11).

Development of Analytical Methods

Analytical methods were developed or modified for carbofuran, warfarin, strychnine, brodifacoum, and reserpine. In addition several

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samples were analyzed for Compound 1080 and zinc phosphide. These methods are required to complete investigations of control techniques in developing countries.

Grooming Behavior and Conditioned Bait Aversion in Rats

By using grooming behavior, materials placed on the fur of a rodent can be delivered by accidental ingestion. Grooming apparently persists in the presence of a noxious taste. However, the relationships between grooming and taste aversion have not been described. This investigation was designed to study such relationships with the hope of finding ways to improve methods of rodent control.

In one study, saccharin was mixed with a "neutral-tasting" jelly and applied to the fur of male Sprague-Dawley[R] rats. Rats that were injected with LiCl after the applications strongly avoided saccharin solutions in subsequent 1-hour, two-choice, drinking tests (saccharin solution vs. water). However, rats injected with NaCl or with plain jelly on the fur did not avoid drinking the saccharin solution. The results indicated that the taste of saccharin was perceived while grooming and that the taste aversion formed in grooming and had been generalized to drinking.

In other studies, rats discriminated between different concentrations of saccharin applied to the fur and in a test solution; decreased saccharin avoidance when preexposed to saccharin on their pelage; discriminated between taste qualities of two materials applied to the pelage; and responded to taste qualities rather than toxic properties when two stimuli, saccharin and LiCl's were applied to the pelage. Saccharin overshadowed NaCl in subsequent drinking tests.

The results suggest that grooming behavior might have some unique applications in rodent control. Examples include: prebaiting to permit a rodent to become familiar with bait taste; formulating toxicants that could be masked by the taste of a familiar food; and inducing a conditional aversion to a food crop or commodity that rats damage. Overall, our results support the hypothesis that taste, paired with postingestinal illness is sufficient to produce conditioned aversion. They do not support the contention that taste aversions require object learning or that toxicity need be an important factor in the likelihood of a material being associated with postingestional illness.

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International Rice Research Institute
National Grains Authority
National Post Harvest Institute for Research and Extension
Bureau of Plant Industry
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National Power Corporation

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[3] Personnel not funded under a PASA but who participated in work associated with or pertinent to this project.

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

[5] Individuals who cooperated with the project in research, extension, or project development activities or who participated as students or trainees.

* New staff members or those who changed assignments during 1980.

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10-11 Mar	Dr. Mike Jaeger	United Nations/FAO Addis Ababa, Ethiopia
10-14 Mar	Dr. Danilo Valencia	Instituto Colombiano Agropecuario, Palmira, Colombia
11 Mar	Mr. William Smythe	Vertebrate Pest Control Centre, Karachi, Pakistan
11 Mar	Dr. Julio Sequeira F.	MIDA, Managua, Nicaragua
4 -16 Apr	Dr. Gaafer Ahmed El Zorgani	Agriculture Research Corporation, Wad Medani, Sudan
14-21 Apr	Mr. Daniel Evans	World Bank, Fed. Islamic Republic of the Comoro Islands
12-13 May	Dr. Terry Korn	New South Wales, Australia
15 May	Dr. Djuro Huber	Yugoslavia
19-23 Jun	Mr. Romeo C. Dizon Mr. Danilo C. Sanchez	Ministry of Agriculture, Iloilo City, Philippines
19 Jun-19 Jul	Mr. Elsafi Mohamed Elmahdi	Khartoum, Sudan and Bowling Green State University, Ohio
9-10 Jul	7 AID interns and 3 staff observers	Washington, D.C.
15-19 Jul	Mr. Philippe Ruelle	United Nations/FAO Dakar, Senegal
4-15 Aug	Mr. Manuel Gonzalez Mr. Tomas Vargas	Secretaria de Estado de Agricultura, Santo Domingo, Dominican Republic

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6-11 Aug	Mr. James Gatimu Mr. Frances Miano Mr. John Ngondi Mr. Ephantus Njeru	Kenya and Bowling Green State University, Ohio
18 Aug	Miss Carolyn M. King	Eastbourne, New Zealand
10-13 Sep	Mr. Jousif Juimale Mr. Ahmed Warsame	Somalia and Bowling Green State University, Ohio
6-11 Oct	Mr. Sandin Smith	Rodent Control Officer, Bahamas

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