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9. ABSTRACT
A PROJECT: To develop safe, effective, and economical control methods suitable and practical for small farmers to reduce crop damage by rats and noxious birds.
DURATION: 1968 ongoing
DEVELOPMENTS: This annual report of the Denver Wildlife Rodent Research Center discusses the program and facilities, staff, research, training and international activities. Studies were conducted in the following areas: effectiveness of modified sustained baiting procedures in reducing rat damage to crops other than rice; a similar study for corn; continued studies on means of reducing rat damage to rice; and a study of bird damage in small ricefield plots at hard dough stage. A method has been adapted for coconuts in which bait is placed monthly in tree crowns. The damage in treated plots dropped to low levels. In a comparative study, both groundbaiting and crown baiting with anticoagulant rodenticides reduced rat activity and damage, but crownbaiting was more effective and cost less. In a trial for reducing rat damage to rice, conducted near the Chico River, the sustained baiting method protected a one hundred hectare baiting site from serious rat damage at low cost and with potentially high economic return. In an investigation on the operational characteristics of a non-lethal electric barrier to exclude rats from a ricefield, non-lethal barriers provided comparable or better protection to three, one-quarter hectare ricefield plots than

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lethal barriers, without the need for a night crew to remove electrocuted animals and without need for daily battery recharges. Two tests were conducted to determine the potential hazard of warfarin to domestic chickens. It was concluded that the use of warfarin represents a low hazard to domestic chickens by accidental poisoning if the recommended baiting program is followed.

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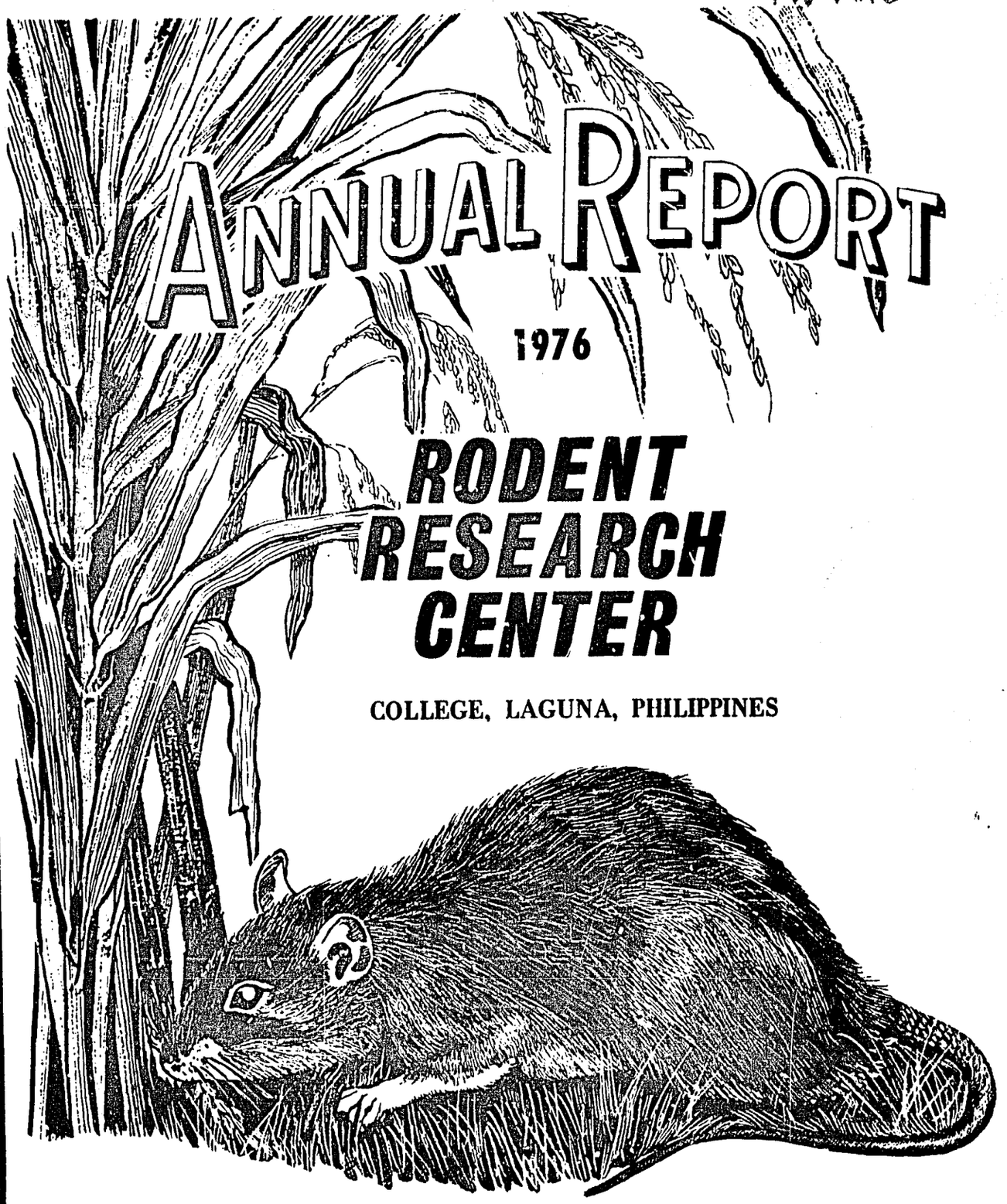
ANNUAL REPORT

1976

RODENT RESEARCH CENTER

COLLEGE, LAGUNA, PHILIPPINES



COOPERATING AGENCIES

REPUBLIC OF THE PHILIPPINES:

National Economic Development Authority
Bureau of Plant Industry
University of the Philippines at Los Baños

UNITED STATES:

Agency for International Development
Denver Wildlife Research Center
Fish and Wildlife Service

109p

RODENT RESEARCH CENTER*
1976 ANNUAL PROGRESS REPORT

PRINCIPAL INVESTIGATORS:

Fernando F. Sanchez, Jesus P. Sumangil, Edwin A. Benigno, Melanda M. Hoque, Justiniano L. Libay, Bernardo E. Marges, Pablo P. Ocampo, and Russell F. Reidinger.

COOPERATING AGENCIES:

Republic of the Philippines -

National Economic and Development Authority
Bureau of Plant Industry
University of the Philippines at Los Baños
College of Agriculture

United States -

Agency for International Development
Fish and Wildlife Service
Denver Wildlife Research Center
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ABSTRACT

During 1976, Rodent Research Center personnel engaged in control method evaluations, development of damage assessment methods, and biological and toxicological studies related to development of control methods of pest rat and bird species. Filipino staff changes included the addition of one field technician, and the resignation of one field technician for a different professional position. Training continued at the Center, with over 3000 individuals, mostly Filipino agricultural technicians, extension agents and key farmers, receiving classroom or field courses in rodent control from Center personnel. In addition, six Center-affiliated scholars continued M.S. degree work and four continued Ph.D. degree work at the University of the Philippines at Los Baños. Use of sustained baiting with chronic rodenticides, a rat damage reduction procedure that includes innovations developed and tested at the Center, was encouraged by the Government of the Philippines through its national rice production program, Masagana-99, and its national rat control programs for non-Masagana-99 areas. Implementation included massive training of extension officers and education of farmers in current control methods. Preliminary surveys in target areas indicated that farmers who followed these recommendations were able to successfully protect their crops from serious rat damage.

Studies were continued on the effectiveness of modified sustained baiting procedures in reducing rat damage to crops other than rice. In coconuts, a method was adapted in which bait is placed monthly in tree crowns. Damage dropped to low levels in treated plots and remained low during 24 months of evaluation. Cost/benefit averaged 1/24 during the second year, when detailed records of copra values were maintained. In a comparative study, both ground-baiting and crown-baiting with anticoagulant rodenticides reduced rat activity and damage, but crown-baiting was more effective and cost less. These results may, in part, be explained by the findings from a study of rat movements between ground level and the tree canopy in a coconut grove. In this study, using a tetracycline marking agent, *Rattus rattus mindanensis*, *R. exulans*, and *R. argentiventer* were present at the ground level, but only *R. r. mindanensis* and *R. exulans* in tree crowns; movement of *R. argentiventer* from ground level to the tree canopy appeared severely restricted or absent. In a study comparing sizes, weights and copra contents, coconuts from an area with no rat control yielded slightly, but significantly, more copra than those from an area which had received effective rodent control for twenty-one months. Partial compensation by trees for heavy rat damage may have occurred in the untreated plots, but compensation

was insufficient to decrease significantly the economic benefits which were gained by following the baiting programs.

In corn, a method was tested which followed closely the procedure recommended for damage reduction in rice. In three, 2-hectare treated plots, damage averaged 84% less than in three reference plots with modest economic benefit. Two studies were aimed at the development of a reliable means of assessing rat damage to corn. To compare reliability, three sampling methods were simulated on distributional maps of rat damage in two cornfields. A systematic method was least variable but a random method was most accurate; a random-clumped method was most variable and least accurate. Area of undamaged corn and its weight were highly correlated ($r = 0.96$, $P << 0.001$) with a single linear equation, a relationship which when combined with an accurate sampling method, might be used to estimate direct corn losses to rats in the field.

Studies were continued on means of reducing rat damage to rice. In a trial conducted near the Chico River in Nueva Ecija, the sustained baiting method effectively protected a 100 hectare baiting site (which was adjacent to marshland, the last of 1900 hectares to be harvested, and represented one of the most difficult situations for protection that is encountered in Philippine ricefields) from serious rat damage, at low cost, and with potentially high economic return. In an investigation of the operational characteristics of a non-lethal electric barrier for exclusion of rats from ricefield, non-lethal barriers provided comparable or better protection to three, one-quarter hectare ricefield plots than lethal barriers, without the need for a night crew to remove electrocuted animals and without the need for daily battery recharges. In a study of rat movements in relation to rice culture, adult rats appeared to move preferentially out of fields being harvested and into fields at earlier stages of development.

In a study of bird damage in small ricefield plots at hard dough stage, damage was significantly greater along the shortest edges than along the other edges and inside the plots. In a study on reproductive behavior, *Lonchura malacca* appeared to have a bimodal breeding season at the study site. In an acute oral toxicity trial, methamidophos was more toxic than carbofuran to *L. punctulata*, but considerably less toxic than carbofuran to *L. leucogaster*, *L. malacca*, and *Passer montanus*. In a small-scale ricefield trial, both methyl carbamate and fenthion appeared to provide some protection from bird damage, but additional, more detailed studies are required to confirm these results.

RODENT RESEARCH CENTER STAFF -- 1976

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* Agency designations: UPLB, University of the Philippines at Los Baños; BPI, Bureau of Plant Industry; NEDA, National Economic and Development Authority; USAID, U.S. Agency for International Development; PSI, Philippine Sugar Institute.

** Staff member was assigned to the Center during part of 1976.

INTRODUCTION

The Rodent Research Center was established in June, 1968, as a joint undertaking of the Government of the Philippines (GOP) and the United States Agency for International Development (USAID). The GOP is represented at the Center by personnel from the Bureau of Plant Industry and the University of the Philippines at Los Baños (UPLB). Additional support and cooperation are furnished by the National Economic and Development Authority, the National Food and Agricultural Council, the National Science Development Board, the Philippine Council for Agricultural and Resources Research, and the Philippine Atomic Energy Commission. USAID is represented by personnel from the Denver Wildlife Research Center of the Department of Interior, U.S. Fish and Wildlife Service. The Center's activities are determined with the advice of a Board composed of a senior member of each of the cooperating agencies.

In May, 1976, the National Crop Protection Center (NCPC) was established on the campus of the UPLB by Presidential Decree No. 936. This Center, along with seven affiliated regional centers, will have primary responsibility for the research, development and dissemination of integrated crop protection systems for the country. At the first Advisory Board meeting of the NCPC, held in November, the Rodent Research Center was incorporated as a unit within the NCPC. Although the NCPC is still in the early stages of development, we look forward to this association as a positive step toward meeting the crop protection needs of the farmer.

Program and Facilities

The programs of the Rodent Research Center are aimed at the goal of reducing vertebrate damage to agricultural crops in the Philippines and other countries of Southeast Asia. To help achieve this goal, the overall program has emphasized not only adaptive research and control-methods evaluation, but also the development of a technical backstop capability to advise regional plant protection agencies and a training capability to encourage rapid use of new findings. During the year, backstop activities have included trouble-shooting visits to specific problem areas, species identifications, advice to agencies on the organization of damage evaluation surveys, control programs, and adaptive research plans, and limited data analysis for agencies involved in cooperative programs. Current research has become more directly focused on field evaluation of control methods on Philippine pest species, while training has assumed increasing importance at the Center.

Staff

The Center staff includes six biologists and two field technicians whose aggregate training covers the areas of agricultural biology, ecology, physiology, control methods evaluation, mammalogy, ornithology, wildlife management, biometrics and entomology. Eleven additional staff members are assigned as full-time support personnel by participating agencies. Mr. Thaddeus A. Obadoni, from Nigeria, spent almost 3 months as a participant staff member of the Center.

Mr. Danilo C. Sanchez, USAID technician, left the Center for a research assignment with CARE in March. Mr. Pablo P. Ocampo joined the Center as a USAID technician in April.

Research

In rice, a trial was conducted on the effectiveness of the sustained baiting program in protecting fields from losses to rats in one of the most difficult damage situations known to occur in the Philippines. Studies were continued on the operational characteristics of non-lethal electric barriers, and preliminary information was obtained on the movement patterns of rats in relation to rice culture. In coconut, a two year evaluation of the effectiveness of crown-baiting with chronic toxicants was completed, the effectiveness and costs of crown-baiting were compared with ground-baiting, the movement patterns of rats between tree crowns and the ground level was studied, and preliminary information was obtained on the relationship between rat damage and copra content of coconuts. In corn, a study was conducted on the effectiveness of a sustained baiting method in reducing rat damage, preliminary information was obtained on the reliability of three sampling methods in estimating rat damage and on the use of area of damage on individual ears as a parameter for predicting corn loss (weight) to rats.

The acute oral toxicity of warfarin to local, domestic chickens was also determined, and studies were continued on toxicity and repellency of several chemicals to Philippine pest bird species. Studies were continued on the biology and damage behavior of several bird species.

Training

Training activities were aimed toward up-dating the knowledge of vertebrate pest control of extension technicians, and to a more limited extent, toward providing experience in the research methodology for professional vertebrate biologists in the Philippines and other countries of Southeast Asia. Again, several hundred visitors from many countries were briefed on Center activities, or given assistance in planning rodent control or research programs. Center staff members participated in the training of more than 3000 agricultural extension personnel from the Bureau of Plant Industry, Bureau of Agricultural Extension, Philippine

National Bank, Agricultural Credit Administration, National Food and Agricultural Council, and other agencies. Sessions on rat control were presented in agricultural production workshops held at IRRI and UPLB. One research trainee from Nigeria spent almost three months at the Center participating in a variety of on-going research programs and working independently on a project proposal for presentation to his parent organization. Three staff continued their pursuit of Ph.D. degrees, one under a PCARR grant, the others with UPLB's reduced fee privilege. Six additional students, who are working for their M.S. degrees and one for his Ph.D. at the UPLB, completed their formal coursework and began their thesis research projects at the Center. Several staff members taught or participated in teaching courses in Vertebrate Pests, Experimental Design, and Wildlife Management at UPLB, while others served as graduate advisers for studies in Applied Zoology.

International Activities

The Center Director was nominated as the invitational speaker for the 1976 Annual Meeting of the Entomological Society of America, held in Honolulu, Hawaii, in November-December. In his keynote address, Director Sanchez summarized the current status of rice pest management in the Philippines. He later attended a conference, co-sponsored by the East-West Food Institute and the University of Hawaii, on the Impact of Pesticide Laws. Earlier in the year he had attended a conference in Hawaii on the Consolidation of Crop Protection Courses and presented a paper on the training needed by the pest management specialist.

Previously plagued by chronic and severe damage, this farmer has lost only negligible amounts of rice to rats since he began using the sustained baiting program in early 1974.

RESEARCH ACTIVITIES

Crown-Baiting in Coconut Trees Using Anticoagulant Rodenticides to Reduce Rat Damage

Introduction

Rat damage to growing coconuts has been a serious problem in the Philippines where it is frequently both chronic and severe. Damage occurs at all stages of growth and may be subject to seasonal changes in intensity when groves are adjacent to harvested crops such as corn, rice, or sugarcane. Banding and ground-baiting with acute or chronic toxicants are often used for rodent control in plantation areas, but small farmers are often unaware of rat damage and use no control at all. Studies of these control techniques which have been conducted in the Philippines and elsewhere usually indicate good results, but cost factors are typically high. Recently, experimental work in Colombia indicated that crown-baiting could be used to good advantage for short-term damage reduction (Woronecki et al., 1973; Elias, 1973). This study was designed as a preliminary test of crown-baiting in the Philippines, using the individual trees as the unit of evaluation and realization of long-term damage reduction as the principal objective.

Portions of this study were supported by the BPI office at Calapan, Mindoro. The study was begun in March 1975, and is still continuing; this report summarizes data through March 1977.

Materials and Methods

A 150-hectare site with a history of chronic rat problems was selected at Barrio San Gelacia, Victoria, Mindoro Oriental. Coconut trees are native varieties, 10-25 years old, from 15-20 meters tall. Four plots (numbered 1-4), each 1 hectare with 100 trees, were chosen. During the first year of the study, two (Plots 1 and 3) were randomly assigned as treated plots while the remaining two (Plots 2 and 4) were designated as reference plots. During the second year of the study, all plots were treated. Plots are separated by at least 150 meters and are at least 200 meters from the nearest edge of the coconut grove. A slough transects the grove, surrounds Plot 4 on three sides and Plot 1 on one side, and separates this plot from a small calamansi (citrus) plantation. A second slough borders one side of Plot 2. Both sloughs, and their weedy banks, however, are separated from the experimental plots by at least several rows of coconut trees. The plot sites were chosen because tree varieties,

ages, surrounding habitat, and crop management practices are similar, and because records maintained by the farmers indicated similar levels of nut production and rat infestation in the past.

In each of the plots, 25 trees were randomly chosen for detailed studies. These trees were numbered 1-25 in Plot 1, 26-50 in Plot 2, 51-75 in Plot 3, and 76-100 in Plot 4. In the treated plots, a single packet of poisoned bait was placed in the fronds of every numbered tree each month; i.e., 25 of the 100 trees in each treated plot were baited. Packets consisted of 0.025% warfarin mixed with binlid and placed in small plastic bags. Packets were placed in trees by climbers (who were collecting data) or by using a long bamboo pole. No baits were used in reference plots. The amount of bait placed in each packet was adjusted to roughly correspond with consumption, so packet sizes ranged from 100 to 200 grams (Table 1). A total of 175 kg of bait was used in Plots 1 and 3 during the 25 months of treatment, or 3.5 kg per month per plot; in Plots 2 and 4, a total of 75 kg of bait was used during 13 months of treatment, or 2.9 kg per month per plot.

Twenty-five rat traps were set in each plot for 3 nights prior to baiting to determine species composition. Relative levels of rat activity were determined monthly by placing inked tiles at the base of 24 randomly selected coconut trees in each plot for 3 consecutive nights and recording the number of tiles with rodent tracks.

Before baiting, all fallen nuts were removed from the plots. Thereafter, monthly records were kept on the numbers of fallen nuts (damaged and undamaged) in each plot and under each numbered tree. To avoid errors, fallen nuts were removed from the areas after they were counted.

The farmer had kept careful records on individual tree production for his entire farm, including the study plots, since July 1973. He used these records as accounts of nut production and to determine wages for harvesters. During the period of treatment, we recorded the number of nuts harvested from each of the numbered trees and from each of the plots. In addition, we maintained harvest records for each tree north of a numbered tree to determine if effects extended beyond trees containing bait. Other economic data are also being collected and will be presented at the end of the study.

Table 1. The amounts of bait placed in tree crowns in experimental coconut plots near Victoria, Mindoro, from March 1975 through March 1977.

Month	Plot 1		Plot 2		Plot 3		Plot 4	
	Bait/ Packet (g)	Total Used (kg)	Bait/ Packet (g)	Total Used (kg)	Bait/ Packet (g)	Total Used (kg)	Bait/ Packet (g)	Total Used (kg)
Mar'75	100	2.5	-	-	100	2.5	-	-
Apr'75	200	5.0	-	-	200	5.0	-	-
May'75	200	5.0	-	-	200	5.0	-	-
Jun'75	200	5.0	-	-	200	5.0	-	-
Jul'75	200	5.0	-	-	200	5.0	-	-
Aug'75	200	5.0	-	-	200	5.0	-	-
Sep'75	150	3.75	-	-	150	3.75	-	-
Oct'75	150	3.75	-	-	150	3.75	-	-
Nov'75	150	3.75	-	-	150	3.75	-	-
Dec'75	150	3.75	-	-	150	3.75	-	-
Jan'76	150	3.75	-	-	150	3.75	-	-
Feb'76	150	3.75	-	-	150	3.75	-	-
Mar'76	150	3.75	150	3.75	150	3.75	150	3.75
Apr'76	150	3.75	150	3.75	150	3.75	150	3.75
May'76	150	3.75	150	3.75	150	3.75	150	3.75
Jun'76	100	2.5	100	2.5	100	2.5	100	2.5
Jul'76	100	2.5	100	2.5	100	2.5	100	2.5
Aug'76	100	2.5	100	2.5	100	2.5	100	2.5
Sep'76	100	2.5	100	2.5	100	2.5	100	2.5
Oct'76	100	2.5	100	2.5	100	2.5	100	2.5
Nov'76	100	2.5	100	2.5	100	2.5	100	2.5
Dec'76	100	2.5	100	2.5	100	2.5	100	2.5
Jan'77	100	2.5	100	2.5	100	2.5	100	2.5
Feb'77	100	2.5	100	2.5	100	2.5	100	2.5
Mar'77	150	3.75	150	3.75	150	3.75	150	3.75

Results and Discussion

As described earlier (Sanchez et al., 1975), Rattus rattus mindanensis were taken most commonly (49%) during the pretreatment trapping period, followed by an almost even distribution of Suncus murinus (20%), R. argentiventer (17%), and R. exulans (14%). Since all traps were placed at the ground level, we do not know or assume that the same distribution of rats occurred in the tree canopy, nor can we deduce which species damage nuts. Since crown-baiting resulted in an almost complete reduction of rat activity at the ground level, we can conclude that there was considerable movement between rats at the ground and canopy levels.

Rat activity, as indicated by tracking tiles, was similar in all plots at the onset of the study (27% vs 31%, treated vs reference plots respectively; Figure 1). By the second month after baiting, activity in the treated plots (1 and 3) had dropped to a negligible level and remained low thereafter. In contrast, rat activity in the reference plots (2 and 4) increased during the rainy season (4-7 months after baiting began in the treated plots; by the sixth month, 60% of the tiles were tracked), then returned to lower levels with the onset of the dry season. We began baiting the reference plots on the twelfth month of the study. Rat activity rose after the first month of baiting, then dropped to levels similar to those observed in the other plots and remained low (compared to pretreatment levels) thereafter. A rise in rat activity in all plots was observed during the last two months of the reporting period; this coincided with harvesting of camote and ricefield crops in areas surrounding the coconut groves and might have been due to immigration of rats from these areas. In response, bait packets have been increased from 100 to 150 grams and rat activity will be followed for the next year to continue observations on the long-term effects of sustained baiting in coconut crowns.

Numbers of fallen, damaged nuts in the treated plots (1 and 3) decreased in a manner similar to rat activity; i.e., by the second month, numbers of dropped damaged nuts had reached a negligible level and remained low thereafter (Figure 2). In reference plots (2 and 4), there was a sharp increase in fallen, damaged nuts at the beginning of the rainy season (from averages of 8 to 44 per month at 5 months after baiting in the treated plots), then a return to lower levels during the dry season. Three months after baiting was initiated in these plots (fifteenth month of the study), numbers of dropped, damaged nuts had reached a negligible level and remained low thereafter.

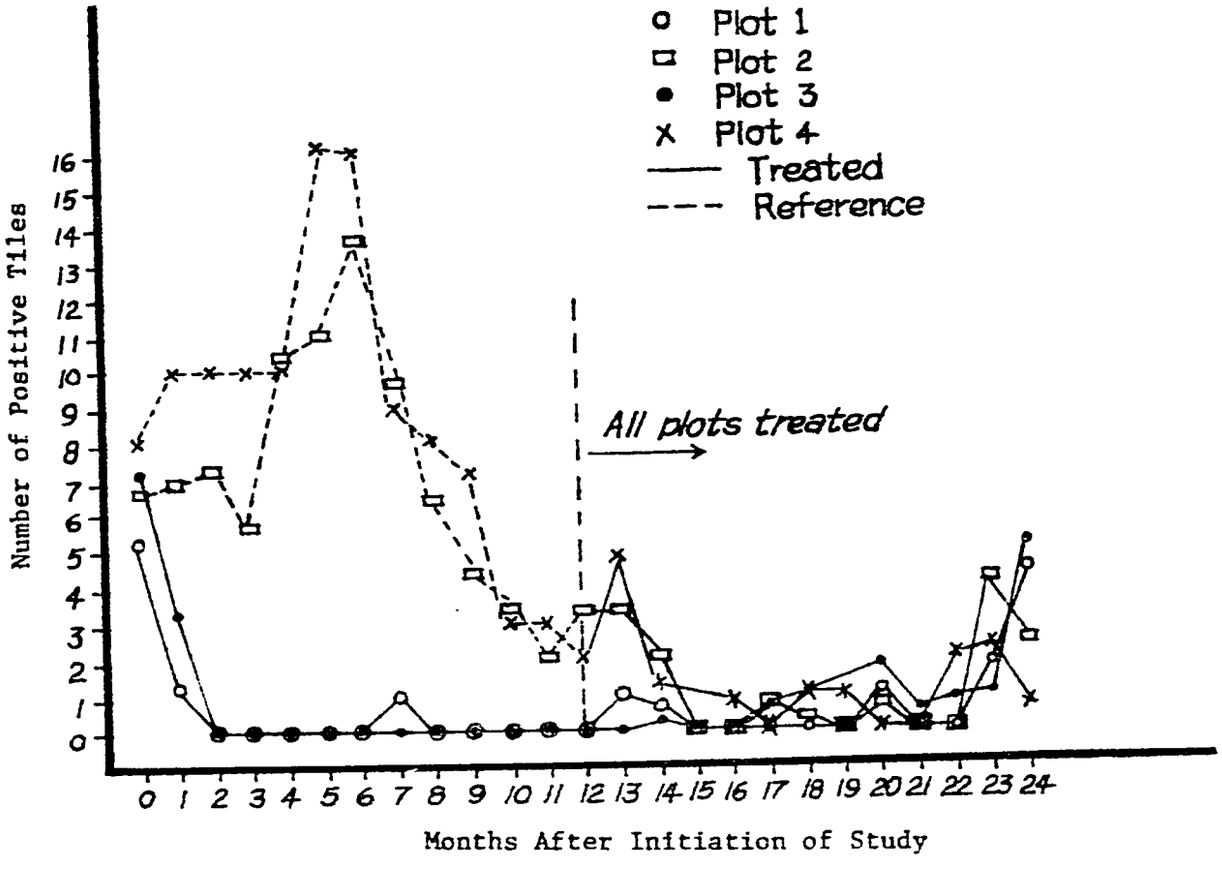

Figure 1. Rat activity in four coconut plots, each one hectare with one hundred trees, near Victoria, Mindoro Oriental. Plots 1 and 3 were treated and Plots 2 and 4 were reference plots during the first year; all plots were treated during the second year. For treatment, twenty-five trees in each plot were crown-baited monthly with anticoagulant rodenticides; reference plots were not baited.

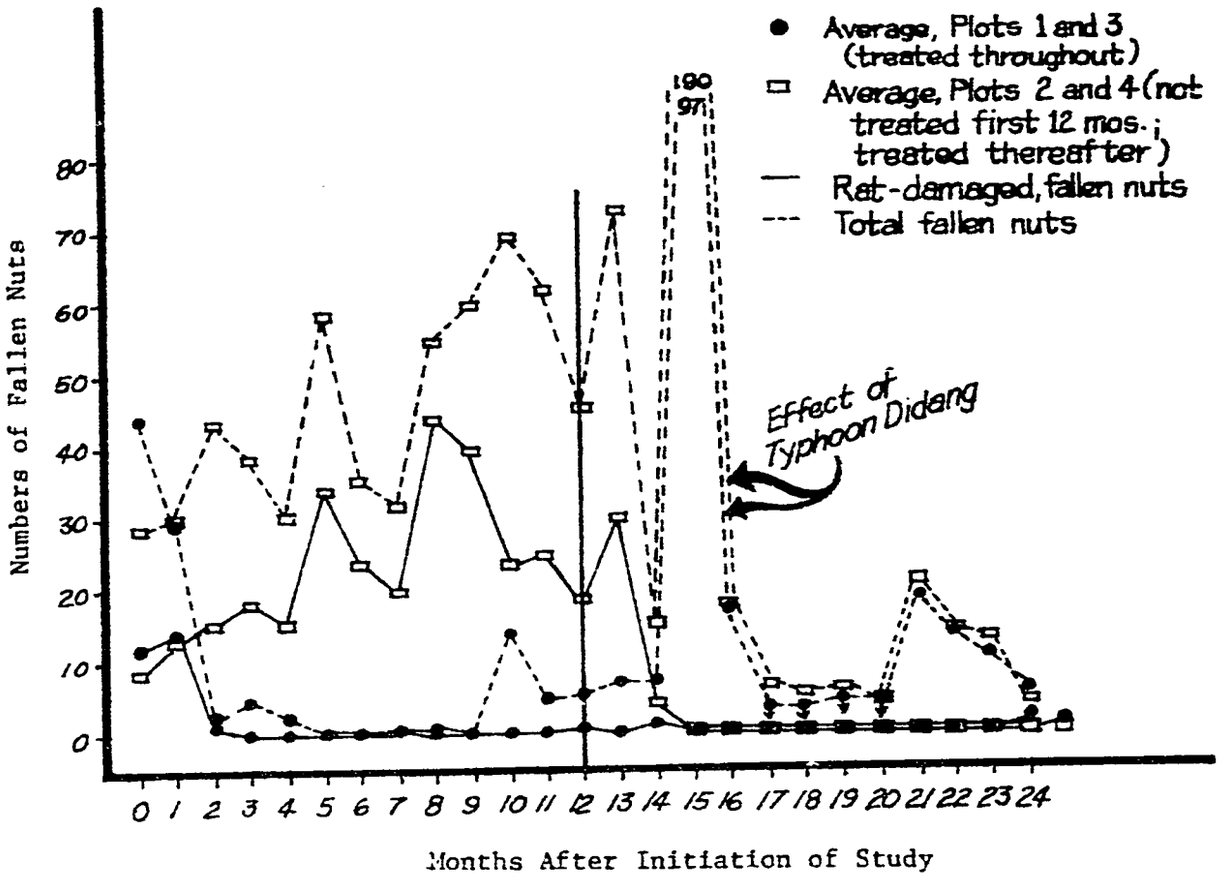

Figure 2. Number of fallen nuts in four coconut plots, each one hectare with one hundred trees, near Victoria, Mindoro Oriental. PLots 1 and 3 were treated and Plots 2 and 4 were reference plots during the first year; all plots were treated during the second year. For treatment, twenty-five trees in each plot were crown-baited monthly with anticoagulant rodenticides; reference plots were not baited.

The total numbers of fallen nuts, including those obviously damaged by rats and those not obviously damaged, generally followed the same patterns as the damaged, fallen nuts with three exceptions: relative increases in fallen, undamaged nuts occurred during the eighth through the twelfth and the twentieth through the twenty-fourth months of the study. In both cases, the increase was during November through March but the causes are unknown. Typhoon Didang, an usually strong tropical storm, swept through the Philippines in May, 1976 (fourteenth month of the study), and its dramatic effect on numbers of fallen, undamaged nuts is shown in Figure 2.

During the period of study reported here, there were seven post-treatment harvests for Plots 1 and 3, and four post-treatment harvests for Plots 2 and 4. For numbered trees in Plots 1 and 3, harvests (nuts per month) during treatment averaged about 2.5 times the last pretreatment harvest; in Plots 2 and 4, harvests during treatment for numbered trees averaged about 2.2 times the four pretreatment harvests. North trees followed the same pattern as the numbered trees, only differences were less accentuated (increase of 1.9 times pretreatment levels; Figure 3).

Harvested nuts from entire plots for pretreatment and post-treatment harvests are presented in Figure 4. In Plots 1 and 3, six pretreatment harvests (20 months) are compared with seven harvests during treatment (24 months). In Plots 2 and 4, nine pretreatment harvests (31 months) are compared with four harvests during treatment (13 months). In Plots 1 and 3, pretreatment harvest levels averaged 2.92 nuts per tree per month, or about 2.5 times greater than the pretreatment levels. In Plots 2 and 4, pretreatment harvest levels averaged 2.57 nuts per tree per month, while post-treatment levels were 6.04 nuts per tree per month, or about 2.35 times greater than the pretreatment levels. We expect that the level of harvest in Plots 2 and 4 will increase ever more relative to pretreatment levels, because these calculations include the three months lag period between initiation of treatment and measured effects of the treatment. Thus, it appears that a general increase of about 2.5 times the pretreatment harvest levels is a reasonable estimate of benefits in each of the experimental plots. The increases in nut production observed for the entire plots are consistent with those measured for individual numbered and north trees within the plots during the periods of treatment.

Since the baiting program was the only major change associated with coconut tree management in the plots, we conclude that most of the increase in nut production was a direct or indirect consequence of the reduced effects of rats. Since the effects of treatment have been maintained for a period of two years in the plots treated initially,

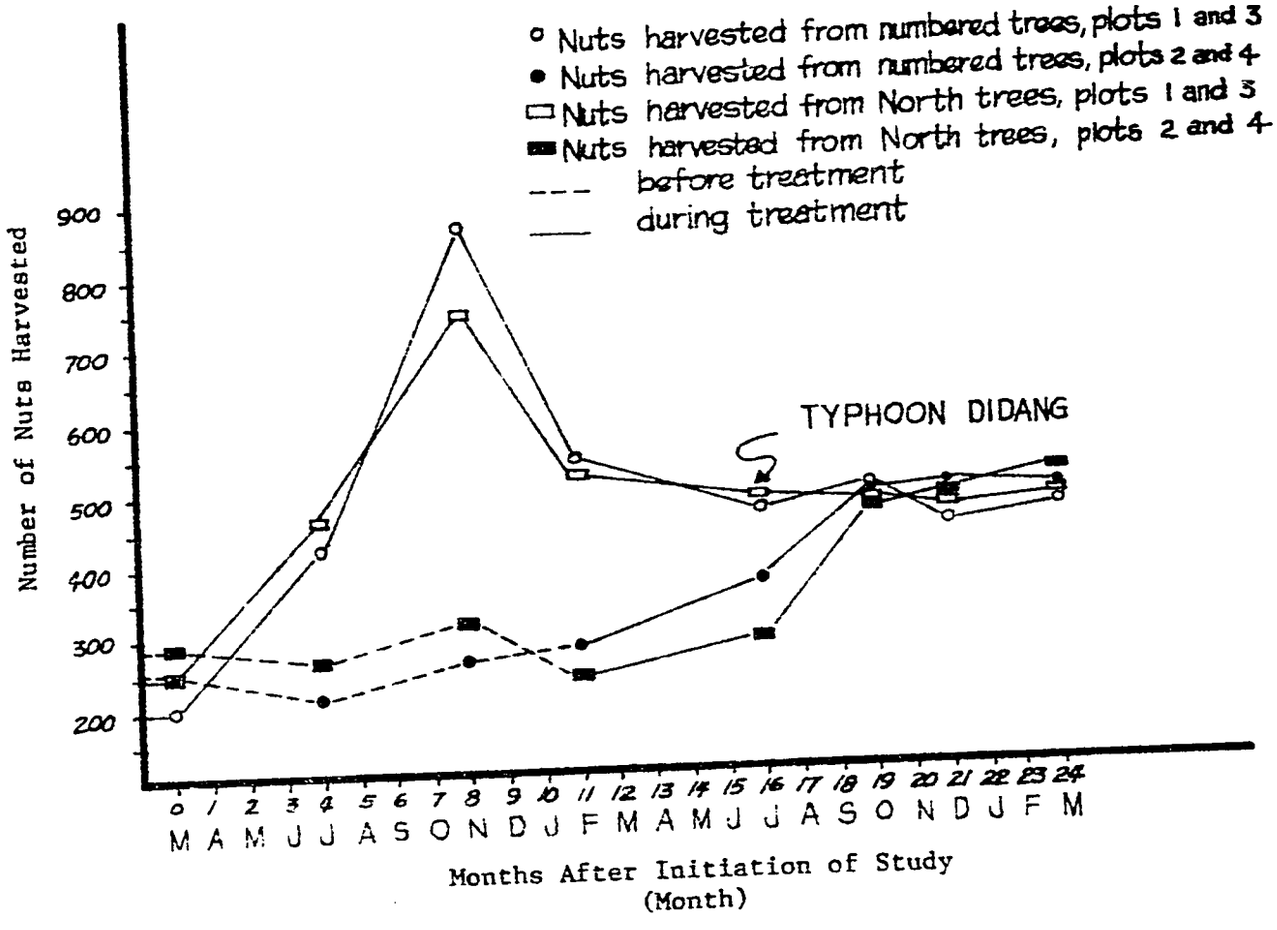

Figure 3. Nuts harvested from 25 numbered coconut trees and nearest trees north of numbered one in four plots near Victoria, Mindoro Oriental. Plots 1 and 3 were treated and Plots 2 and 4 were reference plots during the first year; all plots were treated during the second year. For treatment, numbered trees were crown-baited monthly with anticoagulant rodenticides.

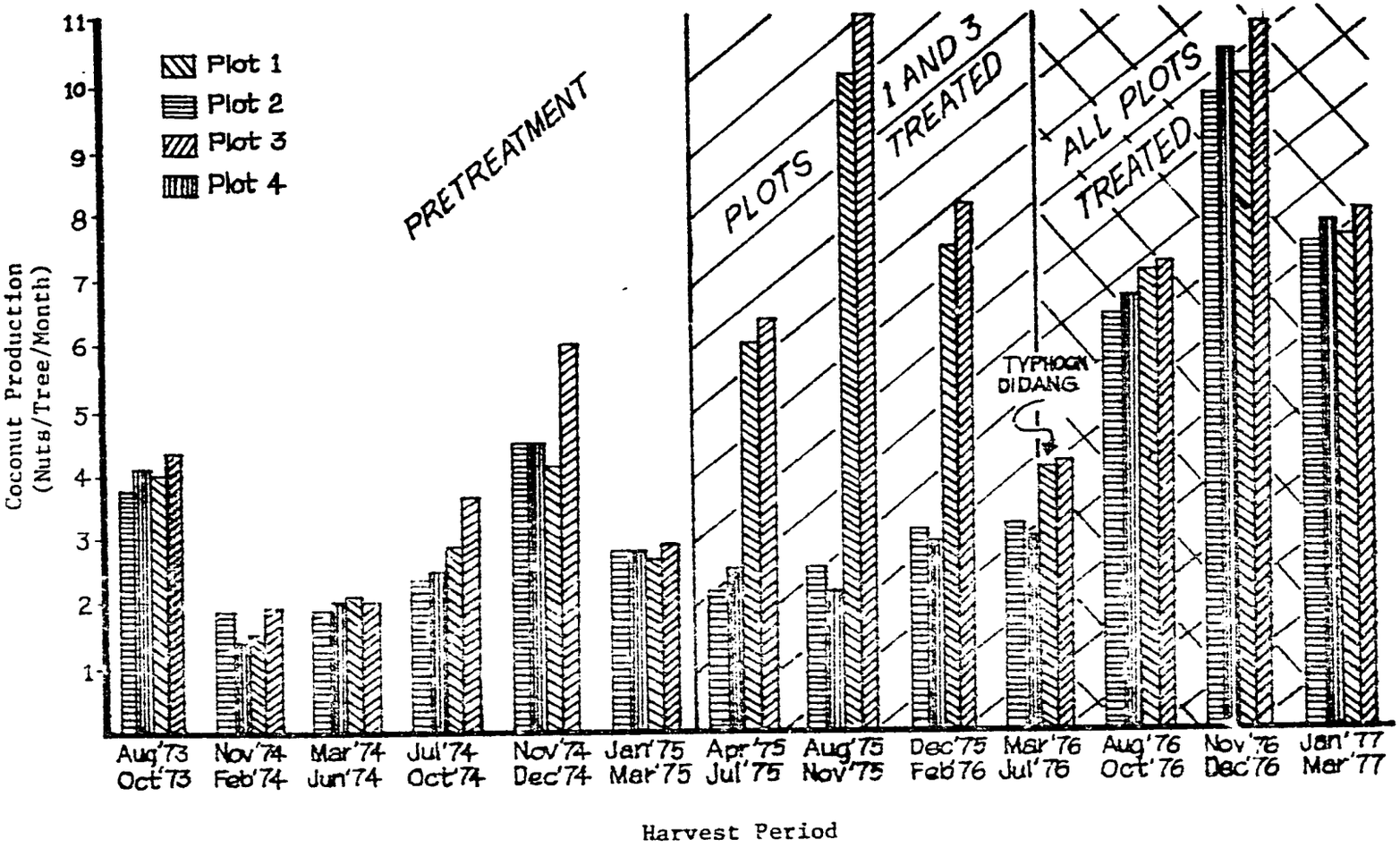

Figure 4. Nut production in four study plots near Victoria, Mindoro Oriental. Plots 1 and 3 were treated and Plots 2 and 4 were reference plots during the first year of the study; all plots were treated during the second year. For treatment, twenty-five trees in each plot were crown-baited monthly with anticoagulant rodenticides; reference plots were not baited. Harvests during treatment are compared with pre-treatment harvests.

we also conclude that the use of this method has the potential of providing long-term relief to coconut damage by rats.

The economic value of individual coconuts in the Philippines varies greatly with supply and demand which makes it somewhat difficult to estimate the potential economic benefit of the procedure. In 1973, farmers earned about ₱0.40 for each coconut. In 1974, values ranged from ₱1.20 to as low as ₱0.15 per nut. Monthly values of copra for 1976 and part of 1977 are presented in Table 2. In Plots 1 and 3, we used about 3.5 kg of bait per plot per month and in Plots 2 and 4, during their period of treatment, we used about 2.9 kg of bait per plot per month at a cost of about ₱7.50 (₱0.075 per tree per month) and ₱6.60 (₱0.066 per tree per month) respectively. If wages for labor are included (typically the farmer would do the work himself -- about 3-4 hours per month), the direct costs for monthly treatment of each tree would be about ₱0.11 - ₱0.12. Based on these figures, the market value of copra, and assuming a 2.5-fold increase in coconut production as a consequence of the baiting program, we estimate that the farmer gained about ₱14,960 gross worth of copra from the direct and indirect effects of the crown baiting program in the four hectares of experimental plots during the period when all plots were treated. Total costs of control are estimated (based on ₱0.12 per tree per month) at ₱624 during the same period, with an overall cost to benefit of about 1/24. As shown in Table 2, cost to benefit ratios calculated at each harvest period varied considerably (from 1/7.3 to 1/41.3), according to the market value of the copra.

We conclude from this preliminary study that sustained crown-baiting with chronic rodenticides provided effective protection from rat damage in all plots during the periods of treatment, with good economic return, and that the crown-baiting method has the potential of providing long-term reduction of coconut damage by rats. The method used in this study, at a cost of about ₱0.11 - ₱0.12 per tree per month, is affordable to the small farmers, but tests should be conducted to determine the general applicability of the procedure in more of the diverse conditions under which coconuts are grown in the Philippines. Future studies with different baiting schedules and placement patterns may further reduce the cost of the method.

Table 2. Estimated economic benefits of crown-baiting in coconuts at study plots near Victoria, Mindoro. Figures are based on costs and benefits for four hectares.

Harvest Month, Year	Harvest Period (Mo.)	Copra ₱/kg	Value ₱/nut*	Nuts Harvested (Total, 4 plots)	Gross Value (₱)	Estimated Benefit Due to Rat Control (₱)**	Estimated Costs of Control (₱)	Cost/ Benefit
Jul,'76	5	1.00	0.40	7320	2928	1757	240	1/7.3
Oct,'76	3	1.80	0.72	8310	5983	3590	144	1/24.9
Dec,'76	2	1.86	0.74	8255	6109	3665	96	1/38.2
Mar,'77	3	2.70	1.08	9180	9914	5948	144	1/41.3
				Total	24,934	14,960	624	1/24.0

* Assumes 2.5 nuts produce about 1 kg of copra (based on 171 nuts sampled over 2 harvests in treated plots: total 68.25 kg copra or 0.40 kg/nut)

** Assumes a 2.5-fold increase in nut production due to effects of rat control.

Movement of Rats Between Tree Crowns and Ground Level in a Coconut Grove

Introduction

Although rat damage is a common problem for Filipino farmers, we have little information on the species causing damage or their behavior in the coconut agroecosystem. During a recent trial of crown-baiting with anticoagulants in study plots near Victoria, Mindoro Oriental, we trapped for three nights prior to baiting to determine species composition in the study plots. R. r. mindanensis was most common (49%), followed by S. murinus (20%), R. argentiventer (17%), and R. exulans (14%; Sanchez et al., 1975). However, all traps were placed at ground level, so that actual distribution of rodent pests causing damage in tree crowns could not be deduced.

In this study, we trapped in both tree crowns and at ground levels to determine relative species composition in a coconut plantation, and used a marking agent to determine movements of rats between tree crowns and the ground level.

Materials and Methods

Two study plots, each consisting of one hectare and about one hundred trees and separated from each other by 300 meters, were selected within a coconut plantation having a long history of chronic rat problems near Victoria, Mindoro Oriental. Plots had similar tree varieties, densities, and cultural practices and appeared to have similar levels of rat damage. Fifty tracking tiles were placed systematically at tree bases in each plot for three consecutive nights and numbers of tracked tiles were recorded the following mornings to determine the degree of similarity of rat activity between plots at the ground level. The numbers of fallen nuts, damaged and undamaged, were counted and recorded to provide an additional comparison of past histories of rat infestation between the plots.

Following collection of this preliminary information, one of the plots (Plot A) was randomly selected for baiting in tree crowns while the other (Plot B) was designated for ground baiting. In Plot A, a single plastic packet containing 100 grams of polished rice with 0.5% tetracycline hydrochloride (TC; marking agent) was placed in the crown of each of 50 randomly selected tree. In Plot B, 50 coconut husk bait stations were assigned to the bases of 50 randomly selected trees, and

a single packet containing 100 grams of polished rice with 0.5% TC was placed in each bait station. Baiting was conducted simultaneously in both plots for one week. After baiting, the unused bait was collected, air dried, and weighed to determine bait consumption in each plot. Then trapping was conducted for three consecutive nights using fifty traps randomly assigned to trees in each plot. For Plot A, which had been crown-baited, traps were placed near base of trees at the ground level. In Plot B, the traps were placed in tree crowns. Rats caught were identified, and their mandibles were removed, brought to the laboratory and exposed to UV light to determine the presence or absence of TC marking agent.

Results and Discussion

Based on our tracking tile data and the numbers of fallen, rat damaged nuts, levels of rat activity were similar in the study plots (Table 3). Positive tiles averaged 65% in Plot A during the three days of measurement, and 69% in Plot B. Likewise, we counted 62 fallen, rat-damaged nuts in Plot A and 70 in Plot B. However, bait consumption at the ground level (Plot B) was almost twice that in the tree crowns (Plot A) during the one week period of exposure (3.0 kg vs 1.6 kg, respectively). Because levels of rat activity in the study plots were similar, we suggest that this difference in bait consumption represents a lower density of rats in tree crowns that at the ground level.

A total of 67 rats were caught for 150 trap nights (45% trap success) at the ground level (Plot A), while only 11 (7.3% trap success) were collected in the tree crowns (Plot B; Table 4). Again, assuming similar levels of rat activity between the study plots, this suggests a lower density of rodents in tree crowns. At the ground level, R. r. mindanensis accounted for 64% of the total catch, while R. exulans and R. argentiventer accounted for 19% and 16% respectively. At the crown level, R. r. mindanensis also accounted for 64% of the catch, while R. exulans accounted for the remaining 36% and no R. argentiventer were caught.

Of rats captured in PLot A, which had been crown-baited and ground-trapped, 65% and 77% of the R. r. mindanensis and R. exulans, respectively, were marked with TC, while none of the 11 R. argentiventer were marked. This again indicates an absence of R. argentiventer from the tree crowns. All of the rats captured in Plot B, which had been ground baited and trapped in the tree crowns, were marked with TC.

Table 3. Rat activity at tree crowns and ground levels in two coconut plots near Victoria, Mindoro Oriental. Each was one hectare with about 100 trees. In Plot A, 50 packets containing 100 g each of polished rice with 1% tetracycline hydrochloride (TC; marking agent) were placed in tree crowns for one week. Plot B received the same treatment except that packets were placed in individual bait stations at ground level.

Rat Activity	Plot A	Plot B
Number positive of 50 tracking tiles (%):		
Day 1	32 (64)	36 (72)
Day 2	32 (64)	30 (60)
Day 3	34 (68)	38 (76)
Average	32.6 (65)	34.6 (69)
Number of fallen coconuts:		
Damaged	62	70
Total	138	112
Bait Consumption (1g):		
Tree crown	1.6	-
Ground level	-	3.0

Table 4. Movement of rats between tree crowns and ground level at two coconut plots near Victoria, Mindoro Oriental. In Plot A, bait containing a marking agent was placed in tree crowns for one week followed by collection of rats with 50 snap traps for 3 consecutive nights. Numbers of each species collected and numbers of marked individuals were recorded. In Plot B, bait was placed at ground level followed by trapping in tree crowns.

	Rattus rattus mindanensis	Rattus exulans	Rattus argentiventer
	Plot A (crown-baited; ground-trapped)		
No. Trapped			
Day 1	28	4	6
Day 2	12	6	4
Day 3	3	3	1
Total	43	13	11
Number Marked	28	10	0
Percentage Marked	65	77	0
	Plot B (ground-baited; crown-trapped)		
No. Trapped			
Day 1	3	1	0
Day 2	3	2	0
Day 3	1	1	0
Total	7	4	0
Number Marked	7	4	0
Percentage Marked	100	100	0

We suggest from this information, taken collectively, that two species, R. r. mindanensis and R. exulans, move actively between the ground level and the tree crown, but that their relative densities are lower in tree crowns than at the ground level and that movement of R. argentiventer between the ground level and the tree canopy is either severely restricted or absent.

Based on the relative amounts of bait consumed and the proportions of marked animals at ground and tree levels, we further suggest that crown-baiting may provide a more selective means than ground baiting of reaching species and, perhaps, population members which actually move into tree crowns and cause damage. From the standpoint of operational rodent control and to the extent that results from this study can be generalized, this may have the dual advantage of less potential for undesirable ecological consequences by concentrating control effects on individuals and species actually causing damage, and of lowered bait consumption and control costs.

A Comparison of Ground-Baiting and Crown-Baiting Using Anticoagulant Rodenticides to Reduce Rat Damage in Coconuts

Introduction

A variety of methods have been used or recommended for use by farmers for reducing rat damage to coconuts in the Philippines, ranging from metal or plastic bands placed around tree trunks and sanitation of groves to the use of chronic or acute rodenticides placed in bait stations on the grove floor. As in other crops, it appears that small differences in control approaches can have significant influence on their effectiveness, impact on non-target organisms, and economic benefits, and it is reasonable to assume that control approaches which most carefully account for the behavior of rodent pests in the coconut agroecosystem will hold the greatest promise for long-term success.

In a previous study (this Annual Report), we were able to show that sustained crown-baiting with anticoagulant rodenticides successfully reduced rodent damage in four experimental plots with good economic return. Based on a preliminary study of movements of rats between tree crowns and the ground level, we suggested that crown-baiting may provide advantages, both economic and environmental, over the more traditional ground-baiting approaches. We report here the results of a trial in which a small coconut farm with a long history of chronic rat damage was provided continuous treatment with anticoagulant rodenticides for a 25 month period; ground-baiting was used during the first thirteen months and crown-baiting during the remaining twelve.

Materials and Methods

A five hectare plantation with 536 trees and a history of chronic rat problems was selectedat Barrio San Gelacia, Victoria, Mindoro Oriental. Coconut trees are native varieties, 15 to 25 years old, from 15-20 meters tall. During a preliminary survey of the area, we counted almost 21,000 fallen nuts; about 94% were dried and decaying and about 41% had obvious signs of rat damage. Almost 80% of the trees had metal bands, most of which were rusted and obviously ineffective.

Trapping was conducted during the pretreatment period. Fifty snap traps were placed at random near tree bases on the grove floor for

three consecutive nights, and catches were identified and recorded. In addition, tracking tiles were placed systematically along four lines within the grove, ten tiles per line. The tiles were inked each afternoon and the number with rat tracks was recorded the following morning for three consecutive days. This procedure was repeated monthly for the duration of the study.

For the period of ground-baiting, debris and fallen nuts were piled into 27 mounds which were evenly dispersed throughout the grove floor at 40-50 meter intervals. Four coconut-husk bait stations were placed around each of the mounds, and filled with binlid containing 0.025% warfarin. Bait stations were checked and refilled 2 or 3 times a week, as required, and amounts of bait added were recorded. After about six months, some of the stations had deteriorated and these were replaced.

For the period of crown-baiting, 56 (10.4%) of the 536 trees were selected for treatment so that baited palms were evenly dispersed throughout the plantation. A plastic packet containing binlid plus 0.025% warfarin was placed monthly in the crowns of each treated palm using a long bamboo pole: during the first four months of baiting, packets containing 200 grams of bait each were used, but this was reduced to 100 grams of bait per packet by the fifth month and maintained at that level for the duration of the study.

For the entire period of the study, numbers of fallen nuts, damaged and undamaged, were counted monthly. To avoid errors, fallen nuts were either removed from the area or placed on the mounds of debris within the plantation.

The farmer had kept careful records on individual tree production for his entire farm since May, 1973, and continued to maintain them during the period of treatment. Other economic data are also being collected and will be presented in the final report of this study.

Results and Discussion

Three nights of trapping before the baiting period resulted in the capture of 55 animals for 150 trap nights, or about a 37% trap success. R. r. mindanensis was most common (55%), followed by R. exulans (22%), S. murinus (15%), and R. argentiventer (9%).

Rat activity, as measured by the tracking tiles, dropped from its initial level of almost 48% to a low of 3% during the first five months of ground-baiting. It remained low for the following two months,

but jumped to 16%, 15% and 18% during the eighth, eleventh and twelfth months of the study respectively. During the entire period of ground-baiting, at least some rat activity was recorded during each tracking period. In contrast, by the third month of crown-baiting in the plantation, no rat activity was measured on the tracking tiles, and activity averaged less than 1% for the rest of the study period (no tiles were tracked for 7 of the 12 months when crown-baiting was used; Figure 5).

The use of ground-baiting reduced fallen, damaged nuts from a pretreatment level of 493 to as low as 4 nuts per month, but increases in rat activity as measured on the eighth, eleventh and twelfth months during ground-baiting were accompanied by corresponding increases in fallen, damaged nuts. In contrast, numbers of fallen nuts remained at or near zero from the third month of crown-baiting until completion of the study (Figure 5).

During the period of treatment with anticoagulants at the ground level, a total of 443 kg of bait was used or about 34 kg per month (6 kg per hectare per month). During the period of crown-baiting, a total of 89.6 kg of bait was used or about 1.5 kg per hectare per month.

It therefore appears that crown-baiting was more effective than ground-baiting in reducing levels of rat activity, as measured both by tracking tiles and by counts of fallen, damaged nuts, and required considerably less bait to reduce and to maintain the lower levels of damage. Although it can be argued that ground-baiting might have reduced damage to comparable levels given additional time, and that amounts of bait required for maintenance of the program would also have been further reduced, the ground-baiting program appeared to have achieved its greatest effects on levels of damage and rat activity by the seventh month of the study and actually appeared less effective by the end of the first year, so that similar or higher levels of bait consumption could probably be anticipated. The gradual drop in both rat activity and numbers of damaged nuts as a result of the ground-baiting program is in stark contrast to the rapid drop when crown-baiting was employed, not only in this plantation but also in four other experimental plots where crown-baiting was used (see first research article, this Annual Report).

During 22 months prior to treatment, the farmer harvested a total of 34,571 nuts or an average of 2.93 nuts per tree per month. During the period of treatment with ground baiting, he harvested an average of 5.82 nuts per tree per month, and during the period of treatment

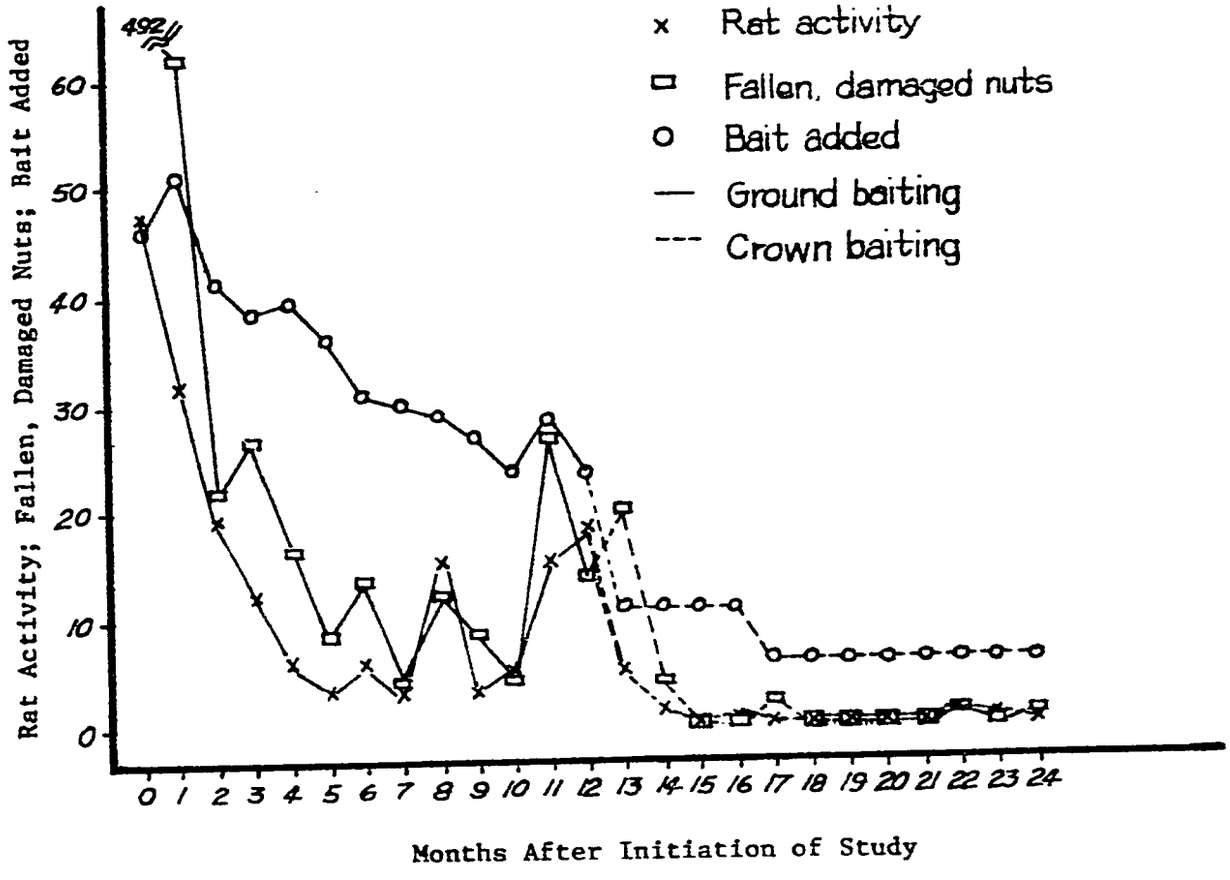

Figure 5. Rat activity (average percentage of tracked tiles), numbers of fallen, damaged nuts, and bait used (kg) in a five hectare coconut plantation in Barrio San Gelacia, Victoria, Mindoro Oriental. The plantation was ground-baited with anticoagulant rodenticides during the first year of the study, then crown-baited during the second year.

with crown-baiting, he averaged 7.19 nuts per tree per month (Figure 6). Because of overlap in the development of nuts and treatment programs, it is difficult to determine the relative effectiveness of the two baiting programs, but it does appear that the farmer realized between a two and 2.5 fold increase in nut production during the period of study. Since rat control was the only major change in cultural practices by the farmer during this period of study, we suggest that this production increase was a consequence of the effective baiting programs which apparently removed rat damage as a limiting factor to coconut production on his plantation.

With an average cost of binlid and bait of ₱1.50 per kg during the two year period of the study, and labor at about ₱1 per hour, the total cost of control during the thirteen months of treatment with ground-baiting is estimated at ₱944 or ₱14.5 per hectare per month. This is based on the use of 443 kg of bait and 280 man-hours of labor (or 5 hours per week) to maintain the bait stations. If costs are based on only the last six months of baiting, after the program had its impact on the rat population and was primarily maintaining the population at a lower level, total cost of control is estimated at ₱571 or ₱8.80 per hectare per month.

In contrast, the total cost of control during the twelve months of treatment with crown-baiting was ₱286 or ₱4.70 per hectare per month. This is based on the use of 90 kg of bait, 672 plastic bags (at ₱0.01 each), and 144 man-hours of labor (or 12 hours per month).

We conclude that both ground-baiting and crown-baiting reduced rat activity and damage at our study site, but that the crown-baiting approach provided more effective protection and cost less, even when compared with the latter period of ground-baiting when primarily maintenance effects and costs are considered. We suggest that crown-baiting may provide a more specific and efficient means than the traditional methods of ground-baiting for reducing losses to coconuts, but that additional studies are required in other parts of the Philippines to determine the general applicability of the method.

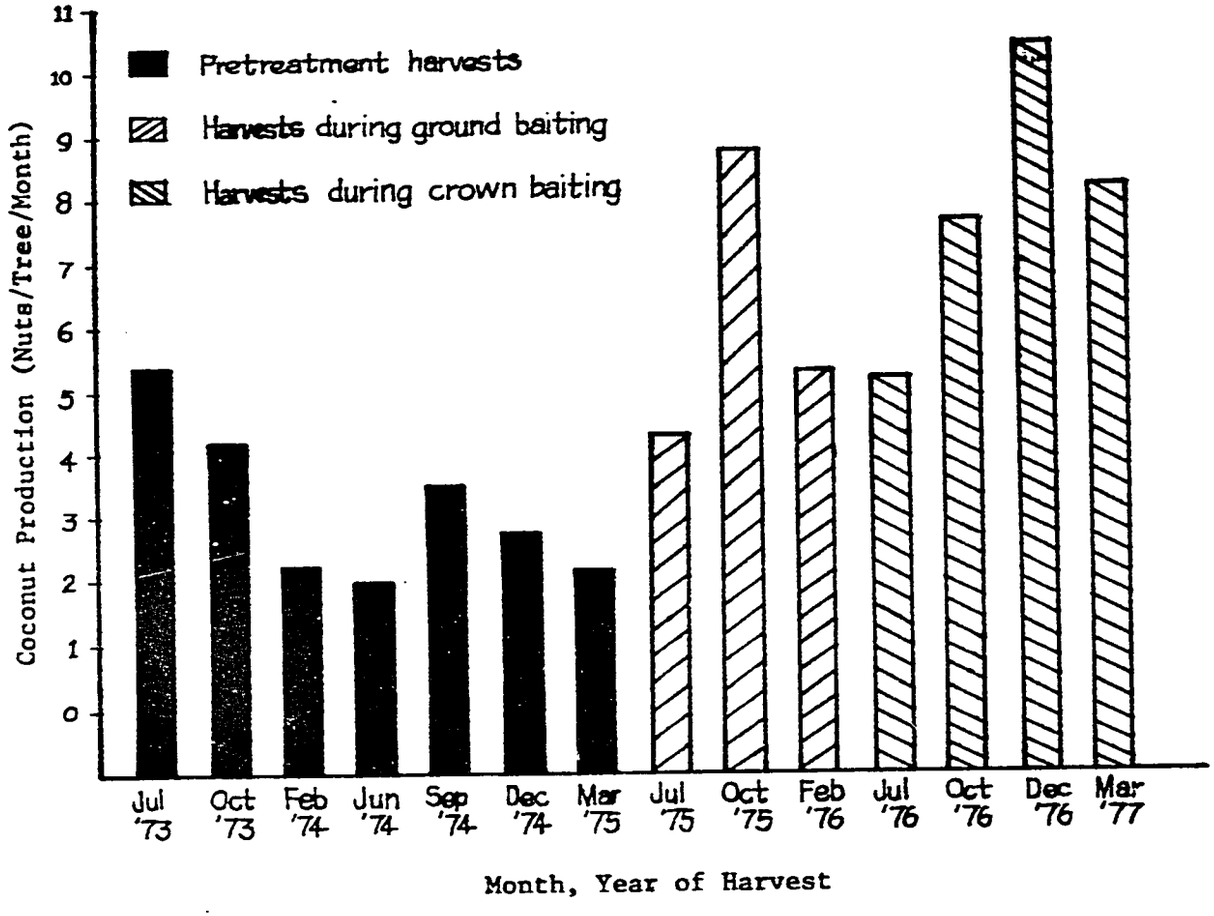

Figure 6. Nuts harvested before and after treatment with anticoagulant rodenticides in a five hectare coconut plantation in Barrio San Gelacia, Victoria, Mindoro Oriental. The plantation was ground-baited during the first year of the study, then crown-baited during the second year.

A Preliminary Investigation of Rat Damage and Copra Content of Coconuts

Introduction

An important consideration in assessing the effects of rat damage to coocnut production and the economic benefits of potential control programs is the possibility that individual trees may be able to compensate for losses by an increase in the number or weight of nuts that reach maturity. In a series of studies on coconut production in the Fiji Islands, for example, Williams (1974a) found that yield from palms having high rat damage were similar to those having low rat damage. During a trial of simulated rat damage at known levels, he found an increase in female flower production, no decrease in harvestable nuts produced and "conservatively" estimated that trees could compensate for 50% of the nuts attacked (Williams, 1974b). A comparison of flesh yield per nut of trees with high and low levels of damage indicated no significant differences.

During recent trials on the effects of crown-baiting with anticoagulants on rat damage to coconuts, we found that actual tree production (nuts/tree/month) increased an average of 2.5 times when compared with pretreatment levels or with reference plots (see first research article, this Annual Report). Economic benefits of the method, based on actual copra production from the treated plots during the last year of the study were ₱3,740 per hectare, with an estimated average cost/benefit of 1/24. It appears that trees were unable to compensate for the level of losses which occurred in our experimental plots by increasing the number of nuts produced, and that the use of anticoagulants in tree crowns removed rat damage as a factor limiting tree production.

In this preliminary study, we compare the size, weights, and copra content of individual nuts from an area which had received effective rodent control (for twenty-one months prior to the study) with nuts taken from an adjacent area which had no rodent control program and which was suffering from heavy rat damage.

Materials and Methods

Sixty nuts were randomly selected from those harvested in one plot (A) near Victoria, Mindoro which had been crown-baited monthly with packets of anticoagulant rodenticide for twenty-one months prior

to the study. For comparison, sixty nuts were randomly selected from those harvested in a nearby plot (B, separated from Plot A by over three hundred meters and a road) which had received no rat control attention and which had many signs of heavy rat damage. Tree varieties, ages, sizes, and cultural practices (except rat control) were similar in the two plots. The greatest horizontal circumference of the husk and the flesh was measured for each of the nuts. In addition, total weight, weight of flesh plus milk, wet weight of flesh, and dry weight of flesh (copra) was taken for each of the nuts. Frequency distributions of measurements and weights were obtained for the samples from each plot, and compared using "one-sided" Students t tests, the hypothesis being, "Are the weights and measurements of nuts in Plot B significantly greater than those in Plot A?"

Results and Discussion

Nuts sampled in Plot A were slightly but not significantly larger than those in Plot B (Table 5). For all other weights and measurements, nuts sampled in Plot B were slightly greater than in Plot A. Flesh wet and dry weights (copra) were slightly, but significantly, greater in the plot having rat damage than in the plot with an effective control program. Wet weight of flesh averaged 0.863 kg per nut in Plot A, 0.050 kg (5.5%) less than in Plot B. Likewise, copra averaged 0.368 kg per nut in samples taken from Plot A, or 0.038 kg (9.4%) less than those taken from Plot B.

During the course of determining economic benefits of baiting procedures in our study plots near Victoria, Mindoro, we took a total of 171 nuts during two harvests (separated by six months) from three study plots which had received treatment for at least one year prior to the collection of samples. Copra weight in these samples averaged 0.40 kg per nut (see first research article in this Annual Report), slightly higher than we found in the samples from Plot A and about the same as those reported in this study for Plot B. Since the time periods involved differ, statistical comparisons between the samples cannot be made, but we use this data to suggest that additional detailed studies are required before compensation by trees for losses to rats by increasing the flesh content of remaining nuts is regarded as a clear possibility.

Assuming that the data presented in this study is a measure of compensation by the trees, the actual proportion of losses (assume about 10%) which are replaced in this manner would be quite meager when compared with the 150% increase in numbers of nuts produced as a result of effective rodent control in our experimental plots.

Table 5. Size and weights of coconuts in two study plots near Victoria, Mindoro. Plot A had been crown-baited with anticoagulant rodenticides for 21 months prior to sample collection and had greatly increased nut production; Plot B had received no attention for rodent control and had heavy damage. Sixty harvested nuts were randomly selected from each plot, then individually measured and weighed.

Measurement	Plot A		Plot B	
	$\bar{x} \pm s.e._{\bar{x}}$*	(Range)	$\bar{x} \pm s.e._{\bar{x}}$*	(Range)
Circumference, total (cm)	63.72 ± 0.31	(55.7–77.0)	63.49 ± 0.25	(55.3–73.1)
Circumference, flesh (cm)	46.71 ± 0.23	(32.2–59.0)	47.26 ± 0.27	(38.2–56.2)
Weight, total wet (kg)	1.89 ± 0.0016	(1.20–2.80)	1.96 ± 0.0022	(1.25–2.75)
Weight, flesh + milk (kg)	1.33 ± 0.0012	(0.50–2.00)	1.34 ± 0.0013	(0.80–1.85)
Weight, flesh wet (kg)	0.863 ± 0.0003**	(0.15–1.20)	0.913 ± 0.0005**	(0.65–1.35)
Weight, flesh dry (copra; kg)	0.368 ± 0.000086***	(0–0.48)	0.406 ± 0.000074***	(0.30–0.56)

* $\bar{x} \pm s.e._{\bar{x}}$ = mean ± standard error of the mean

** Significantly different ($P < 0.05$), Student's *t* test (one-sided)

*** Highly significant different ($P < 0.005$), Student's *t* test (one-sided)

We conclude from this study that partial compensation by trees for heavy rat damage by increasing copra content of remaining nuts may have occurred in our experimental plots. If present, the amount of compensation was slight, insufficient for obvious separation from the fluctuation in copra content of nuts over extended periods of measurement, and inadequate to significantly effect the economic benefits which were gained by following the baiting programs. Additional studies, however, should be conducted on the compensatory mechanisms of palms, particularly in situations where levels of damage are low and cost/benefits of control programs are marginal.

A Field Trial of the Sustained Baiting Method in Ricefields Adjacent to the Chico River, San Antonio, Nueva Ecija

Introduction

During the past few years, we have conducted field trials to determine the effectiveness of the sustained baiting method in areas representing different conditions under which rice is grown in the Philippine (Sanchez et al., 1972-1975). In some trials, we used the barrio as the experimental unit; in others, we used the individual small farm as the experimental unit. We have tested the method in areas where R. r. mindanensis is the major pest species and in areas where R. argentiventer is a common pest. We have tested the method in areas surrounded by ricefields and in areas adjacent to marshland habitat. In all of these trials, the sustained baiting method provided good, sometimes spectacular results.

In this trial, we tested the effectiveness of sustained baiting with chronic toxicants in protecting 100 hectares of ricefields adjacent to marshes bordering the Chico River near San Antonio, Nueva Ecija. We were particularly interested in this location for several reasons: it has been the site of major rat outbreaks in the past and areas adjacent to the marsh along the Chico River suffer chronic, frequently severe rat damage; observations in the area during the year had indicated high levels of rat infestation; planting in the area follows recession of flood waters during the rainy season so that fields are harvested toward the marshland area, leaving the baiting site the last 100 hectares of 1900 to be harvested -- being both last-harvested and adjacent to the marshland virtually assures a high level of chronic rat damage and makes it one of the most difficult situations to protect that we are aware of in the Philippines; and, the harvesting pattern for the area, as described above, provided a unique opportunity to obtain some preliminary information on the movement patterns of rats in relation to harvest and comparative information on rat populations in treated and non-treated areas concurrently.

Materials and Methods

The general study site was about 1900 hectares of contiguous ricefields in Central Luzon, bound on one side by the town of San Antonio, Nueva Ecija, and on the other side (about 2600 meters to the north) by the marshlands adjacent to the Chico River. Planting and harvesting in this site is governed by the recession of floodwaters

which annually cover the ricefields, and which recede gradually toward the marshland. The study site can be divided into four areas according to their planting schedules. Area I consists of about 800 hectares, is about 1400 meters from the marshland and 1200 meters in width. It is most distant from the marsh and floodwaters leave this area first: during the year of our study, ricefields were planted during May and June in this area and harvested during September. Area II consists of about 500 hectares of ricefields, is about 600 meters from the marshland and about 800 meters in width. Planting in this area was initiated in July and fields were harvested in October and November. Area III, also about 500 hectares, is in part adjacent to Area IV and in part adjacent to the marshlands bordering the Chico River, and about 500 meters or more in width. Planting in this area was initiated in August and harvest occurred from November through December. Area IV, the remaining 100 hectares, is low and adjacent to the marshland; it is the last area for recession of floodwater and planting in this area was started in December, completed in January, and the fields were harvested during April and May. There was a period of seven months between harvest in Area I and the initiation of harvest in Area IV.

The study was conducted in two phases: the first to observe the rat populations and their movements as planting and harvesting progressed through each of the areas toward the marsh; the second to determine the effectiveness of the sustained baiting program in protecting the ricefields in Area IV, the last 100 hectares to be harvested.

During the first phase of the study, 15 kg of bait containing 0.5% tetracycline hydrochloride (a marking agent; TC) was placed in about 250 bait stations (described below) which had been randomly dispersed in Area I during the vegetative stage of growth (early July). The bait was left in the field for the remainder of the growing season. Two weeks after the initiation of this baiting, 50 traps were placed in line transects parallel to the marsh and through the middle of Areas I and II; trapping was conducted for three consecutive nights. Trapping was repeated for the following ten months in each area that was in the planting to harvest stage (in a few cases, trapping was also conducted during the land preparation and the post-harvest periods). All rats were identified, age and sex determined, and jaws were examined using ultraviolet light to determine the presence or absence of the marking agent. The data obtained were used to determine the movement patterns of rats as a function of the growing seasons in the area. Since trapping was conducted before and during the baiting program in Area IV, the trapping data was also used as a relative index of the effects of the baiting program on rat populations in the area.

Farmers began land preparation in Area IV during November and planting in December and January. We used tracking tiles to monitor relative levels of rat activity in this area from October through the following May. Ten inked tracking tiles were placed at 100 m intervals along five parallel transects which were separated by about 200 meters each; a total of fifty tiles were used. Tiles showing evidence of rat activity were recorded as positive; unmarked tiles were considered negative. The tiles were checked, cleaned, and re-set for three consecutive days each month.

Baiting was started in this area during the second week of December. The baiting program, which followed closely the Masagana-99 interagency recommendations, was conducted by the farmers under the general supervision of a Rodent Research Center technician. Binlid was used as bait during the early part of the growing season, but later was unavailable, so polished rice was used. A variety of anticoagulant rodenticides available locally were used, following manufacturers' recommendations for mixing and concentrations of active ingredients. Bait stations were also constructed from materials available locally at little or no cost, including bamboo sticks and coconut husks, coconut shells, tin cans, milk cans, bamboo and others. About five baiting points per hectare were chosen initially, and weekly records were maintained of the numbers of bait stations and amounts of bait added at each of the baiting points.

Damage appraisal was conducted within two weeks of harvest in fourteen paddies within Area IV. Since harvesting occurred over a period of 6 weeks, these appraisals were conducted at various times in April and May. Production records were also obtained for fields harvested by the second week of May. Typhoon Didang, however, swept through the area on May 20, inundated it with high flood waters on May 21, and most of the harvest (which was scheduled to begin the following day) in Area IV was lost.

Results and Discussion

In general, trap success of adult rats was similar in Areas I and Area II, but increased greatly in Area III (Table 6). At least two factors were probably responsible for this increase: proximity of Areas III and IV to the marshlands bordering the Chico River, and movement of rats from newly harvested areas (I and II) and their subsequent concentration in remaining unharvested fields (see discussion below). The same general trend was observed in Area IV during the first three months of trapping,

Table 6. Numbers of rats trapped during a study of movement patterns in relation to rice culture in a 1900 hectare study plot near San Antonio, Nueva Ecija. Dates of planting are controlled by recession of floodwaters and is progressively later from Area I to Area IV. Bait mixed with tetracycline was placed in Area I during its growing season; each area was trapped monthly for 3 consecutive nights with 50 traps during and following its growing season.

	Adult Males				Adult Females				Young Males				Young Females			
	Area				Area				Area				Area			
Month	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Jul	11	2	-	-	10	1	-	-	18	0	-	-	31	0	-	-
Aug	8	6	30	-	36	4	24	-	20	1	0	-	34	1	0	-
Sep	10	15	35	-	7	12	40	-	12	20	0	-	35	24	0	-
Oct	6	17	38	-	0	5	57	-	13	33	0	-	23	29	0	-
Nov	-	8	44	28	-	14	40	10	-	20	10	47	-	40	60	0
Dec	-	12	41	36	-	20	41	33	-	26	28	40	-	45	30	10
Jan	-	-	38	39	-	-	27	38	-	-	40	34	-	-	33	5
Feb	-	-	-	6	-	-	-	3	-	-	-	3	-	-	-	2
Mar	-	-	-	2	-	-	-	1	-	-	-	2	-	-	-	1
Apr	-	-	-	8	-	-	-	4	-	-	-	2	-	-	-	6
May	-	-	-	16	-	-	-	21	-	-	-	22	-	-	-	11

but trap success dropped greatly one month after the baiting program was initiated in the area (January) and remained relatively low for the rest of the growing season. Young males and females were collected in each of the areas, with trap success usually greatest toward the end of the growing season. The obvious exception was again in Area IV where trap success of both adult and young rats was reduced considerably after the initiation of the baiting program (Table 6).

Some indications of the movement patterns of rodents in relation to the growing and harvesting periods are provided by analysis of the percentage of trapped animals marked by TC (Table 7). These data are presented on three-dimensional graphs in Figures 7-10, where height and location of columns are used to represent percentage of trapped rats which were marked as a function of area and month. In general, the percentage of trapped adults that were marked by TC was greatest in Area I, and decreased as the trap lines were moved progressively further (in distance and time) from the location of the bait stations, as would be expected by a model for random dispersal of rodents from an area. We note at least one significant variation from this model, however; a drop in the percentage of marked adult rodents in an area during its harvest period and a corresponding increase, sometimes dramatic, of marked animals in adjacent areas where rice is at an earlier stage of development. The collection of two marked adult male rats in Area IV, at least 1400 meters from the bait stations in Area I and as long as seven months after exposure to TC, was also quite surprising. We interpret both of these observations as supporting the hypothesis that rats moved in a non-random directional manner toward the marsh out of harvested fields and into younger ricefields as the growing season for the study site progressed. This movement pattern was most apparent with adult rats, males moving the greatest distance. Dispersal of young rats was observed from Area I to Area II; movements to the other areas, if they occurred would have been obscured by achievement of adulthood two to three months after the young were marked in Area I.

As indicated by both trap success (Table 6) and tracked tiles (Figure 11), rat activity in Area IV began increasing while land was being prepared for planting and as Area III was being harvested. Baiting was initiated in Area IV during the late land preparation stage and continued until harvest. Initially, 2360 bait stations were placed at 500 baiting points within this 100 hectare area, and filled with 28 kg of bait containing anticoagulant rodenticides; stations were checked twice weekly and the numbers of stations and amounts of bait added were adjusted to keep a slight excess over consumption (Table 8). Consumption increased until, by the ninth week after baiting was started, 496 kg of bait was added to 6220

Table 7. Marked rats (percentage of total) which were trapped during a study of movement patterns in relation to rice culture in a 1900 hectare study plot near San Antonio, Nueva Ecija. Dates of planting are controlled by recession of floodwaters and is progressively later from Area I to Area IV. Bait mixed with tetracycline (0.5%) was placed in Area I during its growing period; each area was trapped monthly for 3 consecutive nights with 50 traps during and following its growing season.

	Adult Males				Adult Females				Young Males				Young Females			
	Area				Area				Area				Area			
Month	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Jul	91	0	-	-	80	100	-	-	100	0	-	-	77	0	-	-
Aug	100	0	0	-	78	0	0	-	50	100	0	-	94	0	0	-
Sep	30	47	0	-	43	67	0	-	25	50	0	-	14	12	0	-
Oct	100	42	27	-	0	60	16	-	8	6	0	-	13	3	0	-
Nov	-	50	5	0	-	14	10	0	-	0	0	0	-	0	0	0
Dec	-	17	3	0	-	20	7	0	-	0	0	0	-	0	0	0
Jan	-	-	8	3	-	-	18	0	-	-	0	0	-	-	0	0
Feb	-	-	-	17	-	-	-	0	-	-	-	0	-	-	-	0
Mar	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0
Apr	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0
May	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0

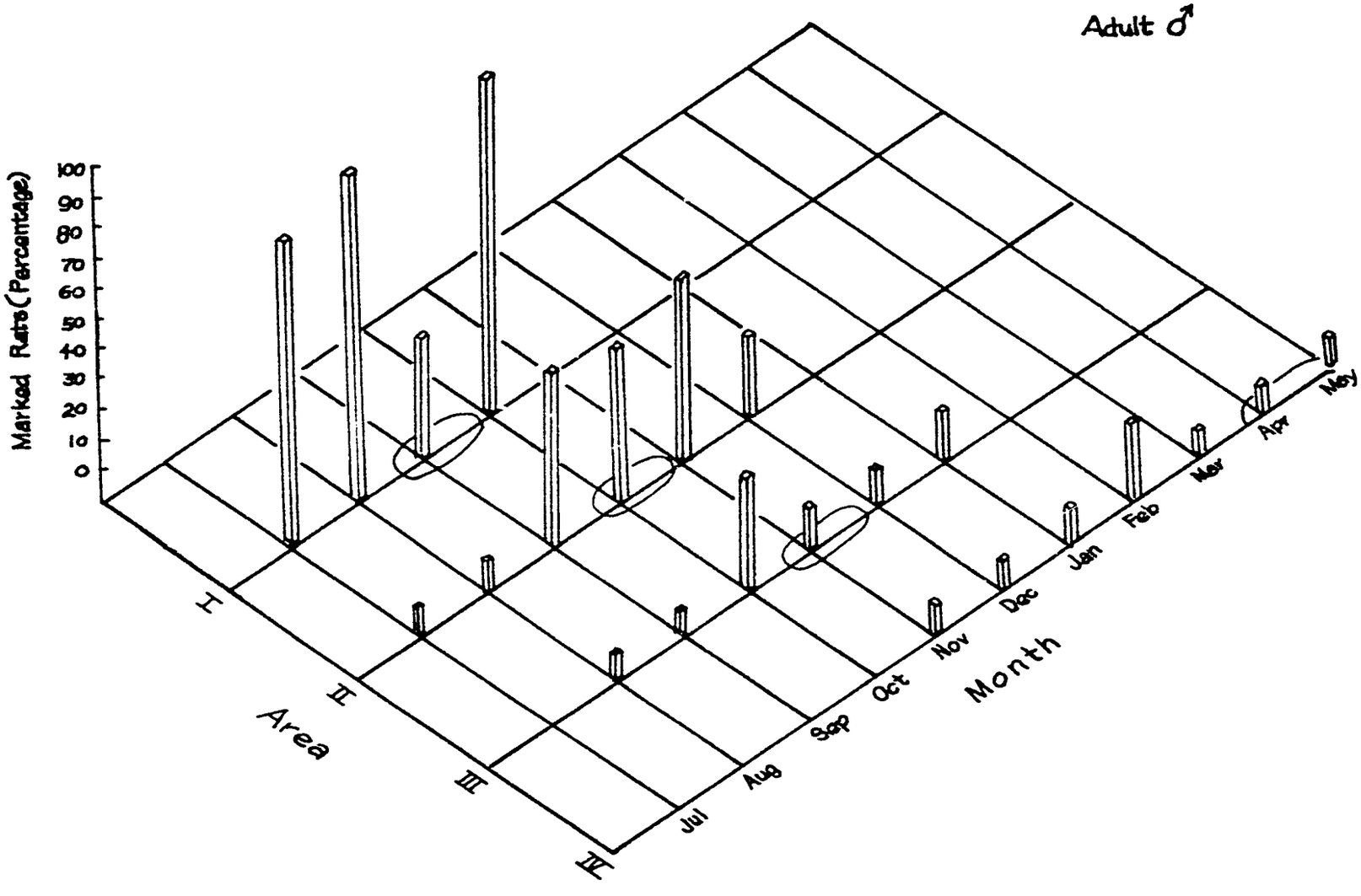

Figure 7. Marked adult male rats (percentage of total) which were trapped during a study of movement patterns in relation to rice culture in a 1900 hectare study site near San Antonio, Nueva Ecija.

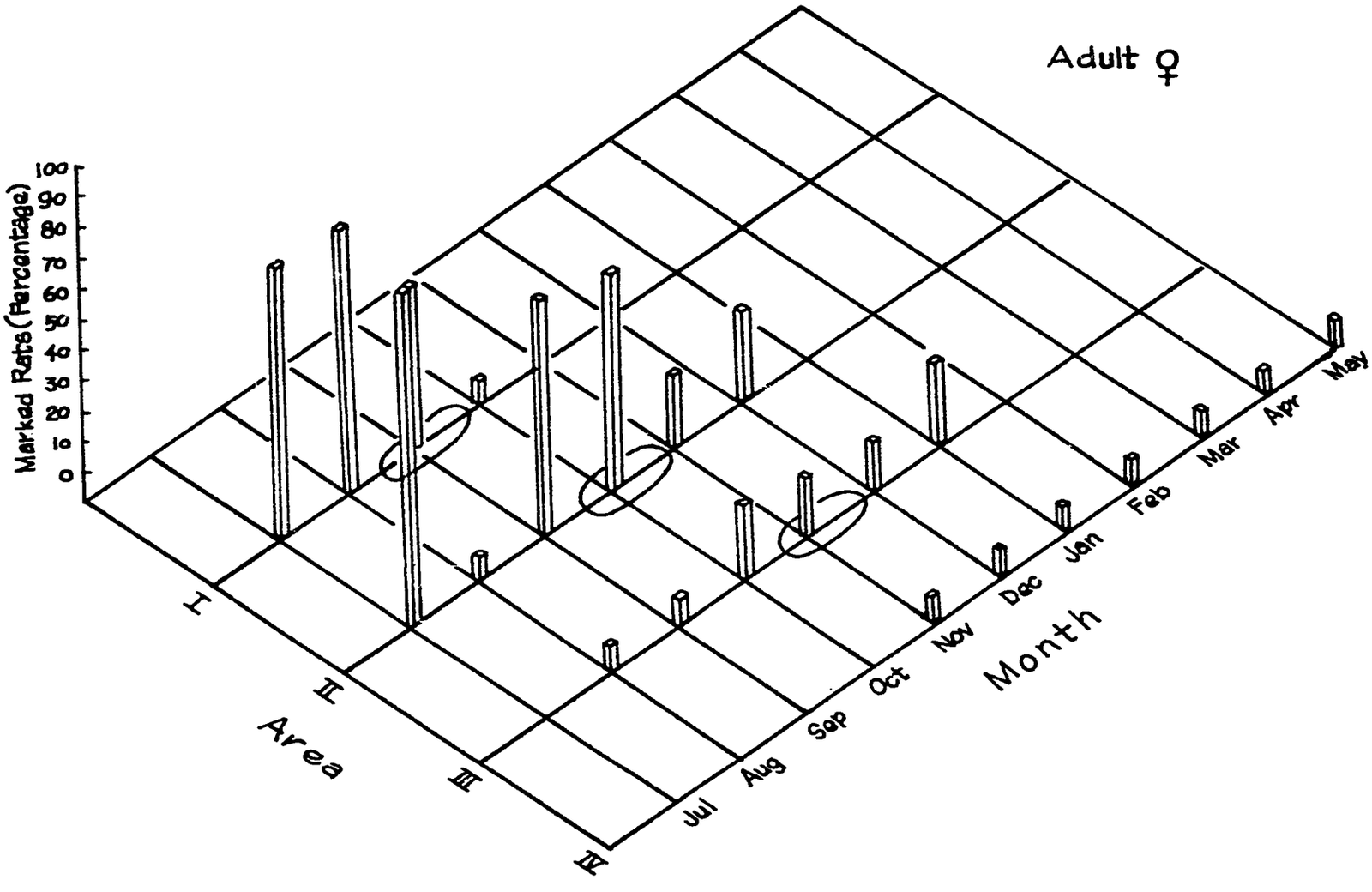

Figure 8. Marked adult female rats (percentage of total) which were trapped during a study of movement patterns in relation to rice culture in a 1900 hectare study site near San Antonio, Nueva Ecija.

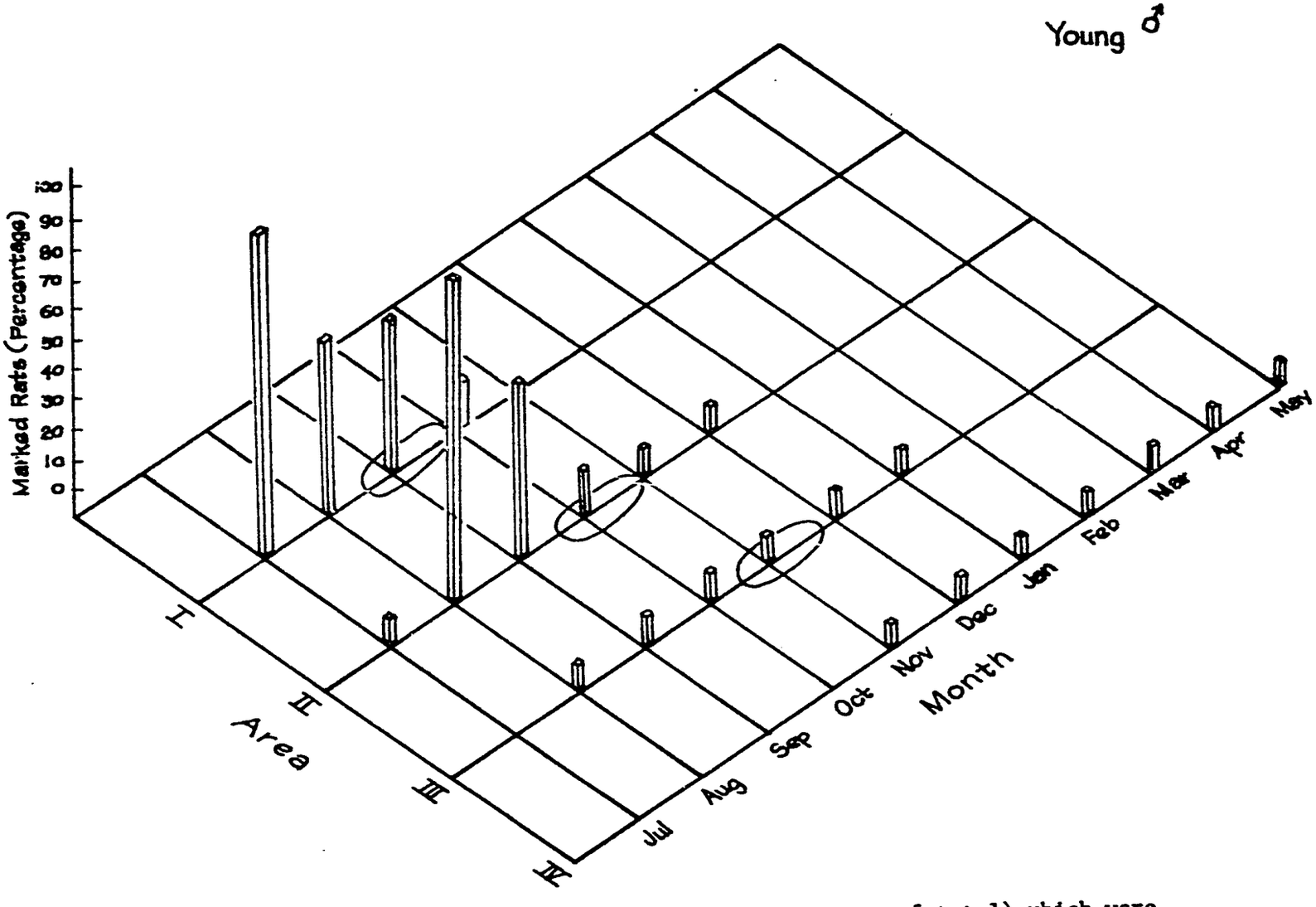

Figure 9. Marked young male rats (percentage of total) which were trapped during a study of movement patterns in relation to rice culture in a 1900 hectare study site near San Antonio, Nueva Ecija.

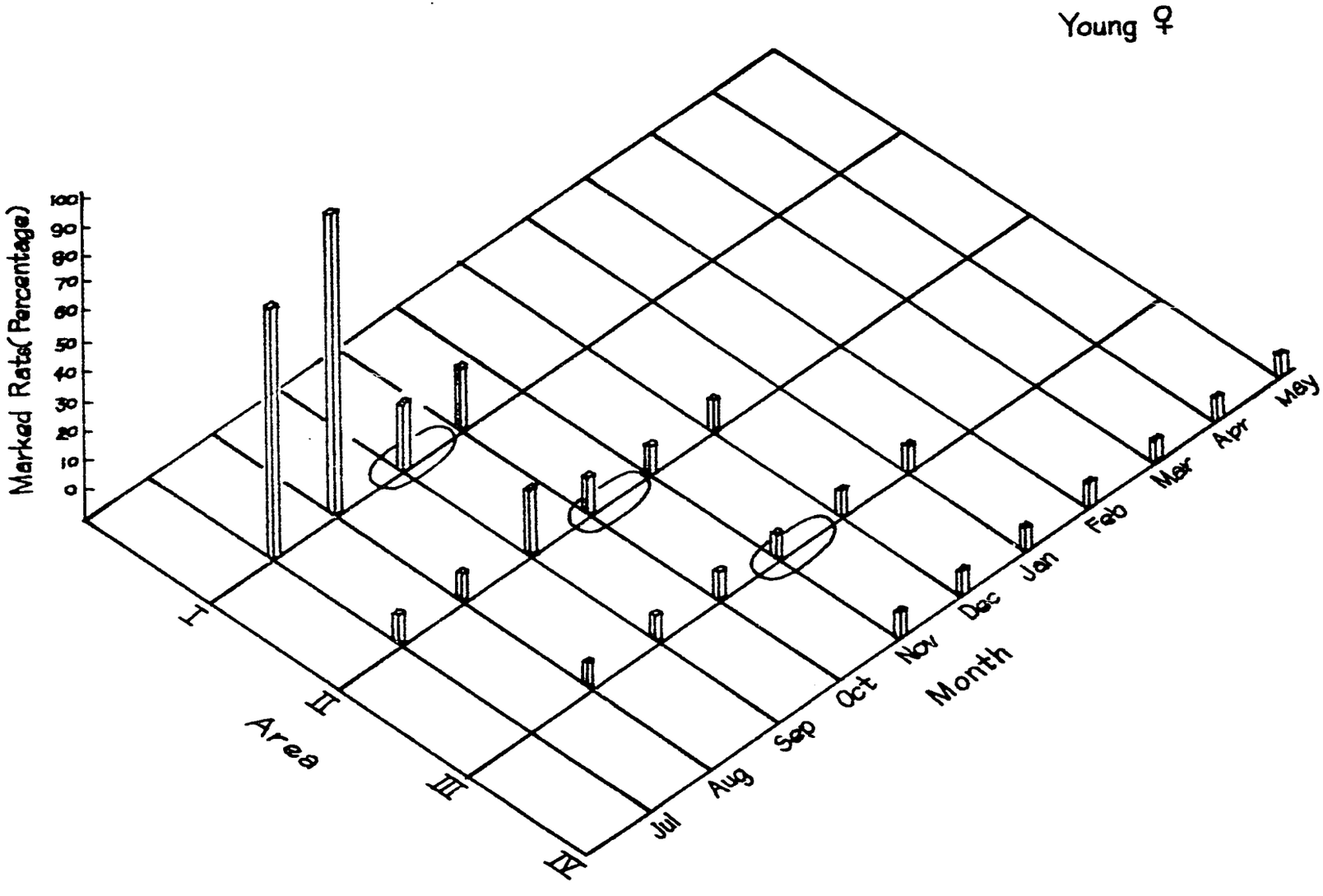

Figure 10. Marked young female rats (percentage of total) which were trapped during a study of movement patterns in relation to rice culture in a 1900 hectare study site near San Antonio, Nueva Ecija.

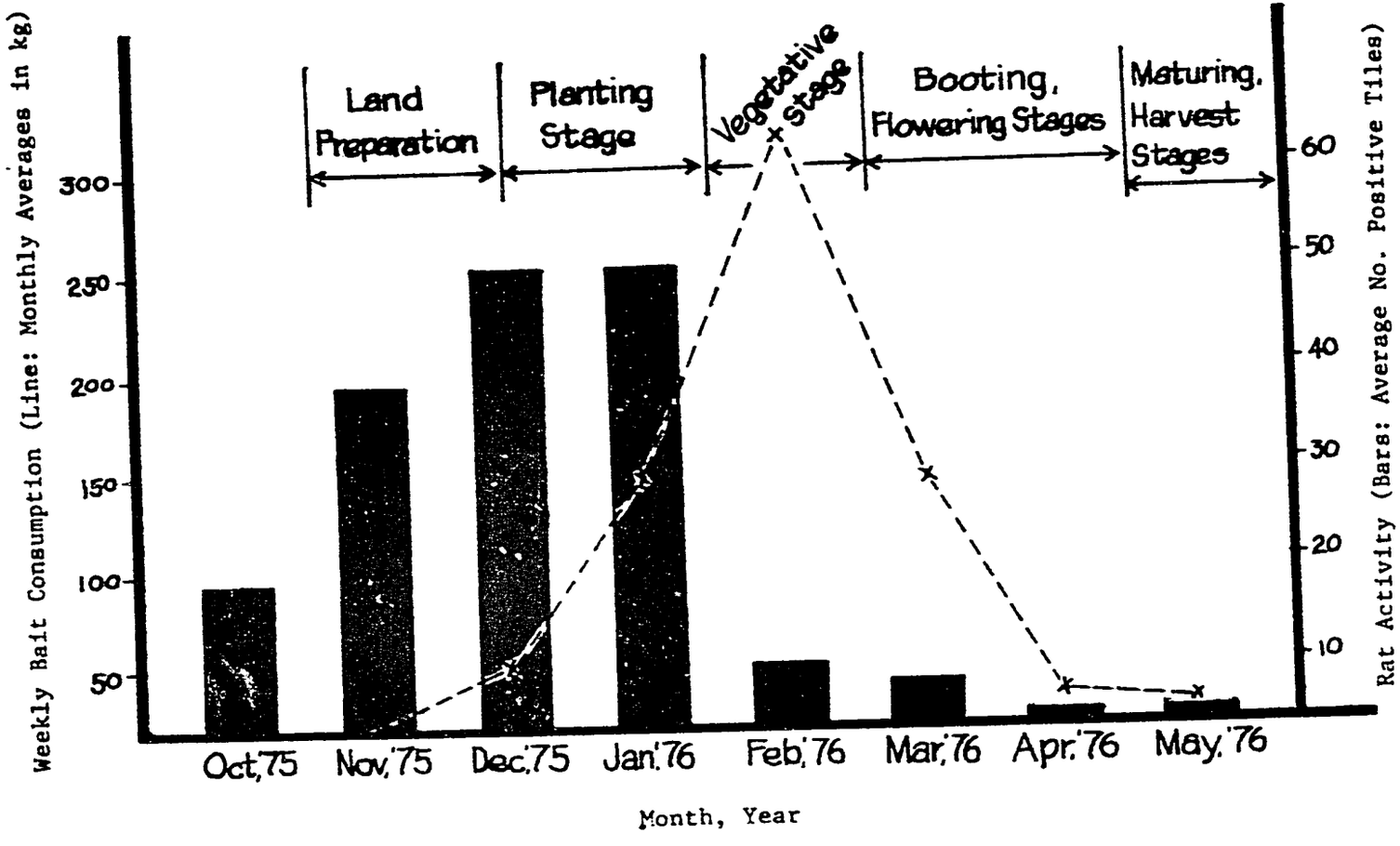

Figure 11. Rat activity as measured by tracking tiles and bait used during a trial of sustained baiting with chronic toxicants in a 100 hectare area of ricefields near San Antonio, Nueva Ecija.

Table 8. Summary of the number of bait stations and amounts of bait added during the crop season in 100 hectares of ricefields employing sustained baiting with chronic toxicants near San Antonio, Nueva Ecija.

Weeks After Baiting Started	Crop Period	Total No. of Stations	Mean No. Stations/ Ha.	Bait Added (Weekly) Total (kg.)	Total (kg./ha)	Mean (g/station)
1	Land preparation	2360	23.6	28	0.28	11.9
2	Land preparation	2360	23.6	45	0.45	19.1
3	Land preparation/ planting	2360	23.6	62	0.62	26.3
4	Land preparation/ planting	2360	23.6	64	0.64	27.1
5	Planting	4998	50.0	69	0.69	13.8
6	Planting	4998	50.0	107	1.07	21.4
7	Planting	5830	58.3	101	1.01	17.3
8	Planting	5900	59.0	305	3.05	51.7
9	Planting	6220	62.2	496	4.96	79.7
10	Vegetative	7080	70.8	283	2.83	40.0
11	Vegetative	10600	106.0	217	2.17	20.5
12	Vegetative	9525	95.2	305	3.05	32.0
13	Vegetative	11575	115.8	88	0.88	7.6
14	Vegetative	11575	115.8	246	2.46	21.2
15	Vegetative	11575	115.8	169	1.69	14.6
16	Booting/ flowering	10250	102.5	154	1.54	15.0
17	Booting/ flowering	10250	102.5	77	0.77	7.5

Table 8 (Continued)

Weeks After Baiting Started	Crop Period	Total No. of Stations	Mean No. Stations/ Ha.	Bait Added (Weekly) Total (kg.)	Total (kg./ha)	Mean (g/station)
18	Booting/ flowering	4890	48.9	66	0.66	13.5
19	Booting/ flowering	2360	23.6	15	0.15	6.4
20	Booting/ flowering	1900	19.0	3	0.03	1.6
21	Maturing	1900	19.0	46	0.46	24.2
22	Maturing	3850	38.5	2	0.02	0.5
23	Maturing	798	8.0	46	0.46	57.5
	Total			2,994		

stations in the area, for an estimated mean consumption of about 80 g per station per week. Addition of bait stations lagged somewhat behind the period of maximum bait addition, so that most bait stations (11,575) were placed in the field during the 13th week after the initiation of baiting. Weekly addition of bait to stations (mean g per station) ranged from 0.5 to almost 80, a lower level than in some of our previous trials; this indicates to us that farmers may have overresponded and placed more stations than necessary in the field, although some of the bait station designs used in this study probably had a lower capacity than those used in previous trials. By the tenth week after baiting until the end of the study, consumption dropped rapidly so that bait consumption during the maturing stage was similar to or less than during the land preparation stage. As shown in Figure 11, the decline in bait consumption corresponded with a drop in rat activity during the vegetative stage, indicating an effective baiting program and a greatly reduced level of rat activity in the area. This effect is further substantiated by our reduced trap success during the period of baiting in Area IV (Table 6).

Based on appraisal of fourteen paddies within Area IV, damage averaged 6.0% tillers cut with a range from 0.8% to 18.8%. Although this is a higher level than we have observed for treated plots in most of our previous trials, it was considerably lower than that observed for fields in Areas II and III where damage ranged from 70% to complete devastation of the fields.

Harvests for most of Area IV were lost when heavy rains and winds of Typhoon Didang flooded the fields. Only six of the hectares were harvested before the floods, but these provided a total of 450 cavans of rice, or 75 cavans per hectare. In contrast, many of the farmers that we interviewed in Area II had harvested two weeks early to salvage what rice they could before the rats completely devastated their fields and reported yields which averaged about 12 cavans per hectare; and, most of the farmers in Area III reported complete loss of their rice to rats.

Despite the intense levels of rat infestation in Area IV, we estimate the cost for materials to conduct the baiting program at less than ₱50 per hectare (about 30 kilograms of bait with anticoagulant at ₱1.60 per kilogram; negligible costs for materials to construct bait stations); labor, roughly one hour per hectare per week, were provided by the farmers at little or no cost. Total costs for control could therefore be regained by an increase in production of one or two canvas of rice per hectare.

From the first phase of this study, we conclude that movements of rats over wide areas of ricefields can be greatly influenced by the planting and harvesting patterns of the area; in this study, rats appeared to move out of fields being harvested and into fields at earlier stages of growth. Since planting and harvesting was determined by the recession of floodwaters, movement of rats into younger fields may have been an important factor in the observed inverse relation between rat densities and distance from the marshland.

From the second phase of the study, we conclude that sustained baiting effectively protected the one hundred hectare baiting site (which was the last of 1900 hectares in the area to be harvested, was adjacent to marshland habitat, and represented one of the most severe situations for rat damage that is encountered in Philippine ricefields) from serious rat damage, at low cost, and with potentially high economic return.

A Comparison of the Effectiveness of Non-Lethal and Lethal Electric Barriers in Reducing Rat Damage to Rice

Introduction

In a preliminary trial during 1975, non-lethal electric barriers protected two, one-quarter hectare ricefield plots from rat damage (Sanchez et al., 1975). During the trial, we observed attempts by rats to cross the barriers only during the first few days of their operation after which most rats appeared to avoid the barriers and the enclosed rice. Fenced areas averaged 0.7% tillers cut at harvest while adjacent unfenced areas averaged 13.5% tillers cut. Based on this trial, we concluded that non-lethal barriers hold the potential of reducing crop losses to rat damage and that the observations on rat behavior during the trial were consistent with the proposed theoretical operation of the fences (i.e., rats, upon repeated contact, are trained to avoid the barrier and serve as a biological buffer to prevent access to the enclosed area by untrained rats).

To obtain more information on the effectiveness of the non-lethal electric barriers, and to compare its operational characteristics with those of a lethal one, we conducted an additional small-scale field trial during the dry season on the experimental plots of the International Rice Research Institute (IRRI). We appreciate the cooperation of IRRI staff in providing experimental plots, and some of the fencing materials and labor for the study.

Materials and Methods

Six plots, about one-quarter hectare each, planted to different high yielding varieties from three weeks after transplant (WAT) to booting stage were provided for the study. Plots were paired, one lethal barrier and one non-lethal barrier, in three different areas (A-C) along the periphery of IRRI experimental fields. Areas A and B were adjacent to an uncultivated highway embankment and Area C was surrounded on two sides by uncultivated fields and a small stream. All three areas have been sites of heavy rat infestation in the past.

The design and operation of the lethal fences at IRRI have already been described (Ramos, 1970; Sanchez et al., 1975). Chicken wire fencing (1.2 cm mesh, 35 cm tall), supported by bamboo stakes at one meter intervals, is placed in the paddy, about 0.1 to 0.5 meters from the dikes. Plastic insulators are fastened to the bamboo poles near

the top of the fence and two strands of 18-20 gauge galvanized steel or copper wires are stretched between the insulators. Power is supplied by six or twelve volt car batteries, but first passes through a vibrator and a transformer so that 125 volts alternating current (AC) is supplied on the line. Batteries are recharged daily. Fences are electrified from sunset to sunrise and encompass up to 65 hectares of experimental plots. A crew of at least thirty staff maintain the fences at night and remove electrocuted animals which short the fences and render them inoperative. Removal of animals involves a complicated and time consuming procedure. When a fence becomes inoperative, an electric bulb lights to alert a crewman. The crewman patrols the fence until he locates the cause and corrects it.

The design of the non-lethal fence was identical to that of the lethal ones except that two rows of wires were installed on double sets of porcelain or plastic insulators along the outside of the fence; one row was about 13 cm above the ground, the second row was about 28 cm. The top 2.5 cm of the chicken fence was usually curled outward. The charge on the fence was direct current (DC), with the fence and outer rows of wire negative, and the central wires positive. A shocker was inserted between a twelve volt car battery and the line to give high voltage pulses (0.3 second) at 0.7 second intervals. Except for a few brief periods of short-circuit problems, the non-lethal fences were operated continuously from the start to the end of the study. Batteries were recharged as required (when voltage dropped below 800) for each of the fences.

To learn more about the performance of the non-lethal electric fences, temperature and relative humidity (percentage) were recorded in the study areas and voltage on the non-lethal electric fences three times daily: early morning, noon and late afternoon from 10-13 WAT. When short-circuits occurred, their sources were recorded. At Area C, times during which the lethal and non-lethal fences became inoperative were recorded weekly during an observation period from 1700 to 2200, 10-13 WAT.

Tracking tiles were used to compare rat activity within and surrounding areas protected by the barriers. Ten tracking tiles were placed along the outside of each of the fences, and ten at similar locations inside the fences for three consecutive days and nights at the vegetative, booting and the maturing stages of rice growth. The inked tiles were checked shortly after sunrise and shortly before sunset and those with signs of rat activity were reported as positive.

In addition to tracking tiles, equal lengths of the lethal and the non-lethal fences in Area C were observed from 1700 to 2200 once a week using red light, and signs and nature of rat activity were recorded. At harvest, damage appraisal was conducted in each of the plots using a tiller cutting index.

Results and Discussion

Mean voltage of the non-lethal fences was greatest during mid-day and lowest during the early morning (Table 9), and appeared inversely related to the relative humidity. Temperature was greatest during the mid-day readings, but lowest in the evening. Correlations of individual relative humidity and voltage readings were not significant, however, so that other factors (such as conditions of batteries, wire connections, and presence of weeds) probably exerted a greater influence in determining the voltage levels of the non-lethal barriers. Batteries used to operate the lethal fences were recharged daily; in contrast, two of the non-lethal fences were recharged only once during the two-month period of study, and one of the fences (in Area B) was recharged twice.

Daytime malfunctions of the non-lethal fences were observed only six times during the study, five of these occurring at the fence in Area A. Two of the shortages were caused by contact of positive and negative wires, two by dead animals (one rat and one toad) placed across the wires, one by disconnection of the wires from the shocker, and one by the excessive rains and winds of Typhoon Didang. At least three of these malfunctions were the result of vandalism.

No malfunctions of the non-lethal fence occurred during the four periods (total of 17.7 hours) of night-time observations in Area C. In contrast, the lethal fence was made inoperative eleven times for a total of 0.96 hours (or 5.4% of the total observation time), always because an animal had contacted and caused a short-circuit in the fence. In most cases, rats approached the fences and moved along the outside at ground level; only a few of the rats that we observed actually attempted to climb the fence and enter the paddy.

Tracking tile data were normalized ($\sqrt{\text{actual data} + 0.5}$) and treated as a time-replicated factorial experiment with a completely randomized design. Main effects were compared by HSD (Honestly Significant Difference; Table 10). Rat activity increased with growing season so that significantly more tiles were tracked during the early- to late-maturing period than during the earlier stages of rice growth ($P < 0.05$). Activity outside the barriers was significantly

Table 9. Mean temperature and relative humidity at early morning (0645-0830), mid-day (1200-1400), and early evening (1800-2000) for six study plots, and mean voltage for non-lethal barriers during a field trial at the International Rice Research Institute, summer dry season.

	Measurement Summary		
	Sample Size	Mean	Range
Voltage*			
Morning	58	1814	600-4000
Mid-day	54	2259	1000-7500
Evening	60	2055	600-7500
Temperature (^{o}F)			
Morning	20	84.8	80-98
Mid-day	18	90.0	83-98
Evening	19	82.9	78-88
Relative Humidity (%)			
Morning	20	76.0	43-87
Mid-day	18	71.5	57-89
Evening	19	77.7	60-91

* Measured with a "Voltage Tester, VT-100"

Table 10. Morning measurements of rat activity reported as the average percentage of tracked tiles for three consecutive nights each area and period. Ten tiles were placed outside and ten inside the barriers each night at three study sites during the dry season on IRRI experimental plots. Transformed data ($\sqrt{x + 0.5}$) are in parenthesis. Evening measurements were all negative except one in area B, non-lethal fence (outside) during the 3 WAT-booting period.

Period*	Lethal Barriers				Non-lethal Barriers			
	Area A	Area B	Area C	Average	Area A	Area B	Area C	Average
Tiles Placed Outside Barriers								
1 (3 WAT-Booting)	0(0.71)	3(1.87)	0(0.71)	1(1.10)	7(2.74)	7(2.74)	0(0.71)	4(2.06)
2 (Booting-Early Maturing)	3(1.87)	7(2.74)	13(3.67)	8(2.76)	17(4.18)	7(2.74)	7(2.74)	10(3.22)
3 (Early-Late Maturing)	23(4.85)	47(6.84)	37(6.12)	36(5.95)	43(6.60)	40(6.36)	23(4.85)	36(5.94)
1-3 (Average, All Periods)	9(2.48)	19(3.83)	17(3.50)	15(3.27)	22(4.51)	18(3.95)	10(2.77)	17(3.74)
Tiles Placed Inside Barriers								
1 (3 WAT-Booting)	0(0.71)	0(0.71)	0(0.71)	0(0.71)	0(0.71)	0(0.71)	0(0.71)	0(0.71)
2 (Booting-Early Maturing)	0(0.71)	3(1.87)	0(0.71)	1(1.10)	0(0.71)	0(0.71)	0(0.71)	0(0.71)
3 (Early-Late Maturing)	0(0.71)	30(5.52)	10(3.24)	13(3.16)	0(0.71)	3(1.87)	7(2.74)	3(1.77)
1-3 (Average, All Periods)	0(0.71)	11(2.70)	3(1.55)	5(1.65)	0(0.71)	1(1.10)	2(1.39)	1(1.06)

* Means for major effects were separated by HSD ($P<0.05$) following analysis of variance; activity during Period 3 > Period 1 and Period 2; activity outside barriers > inside barriers.

($P < 0.05$) greater than inside the barriers, so that both designs appeared to afford some protection from rats. Rat activity, however, was greater within plots surrounded by lethal barriers than within those surrounded by the non-lethal barriers, average 5% vs. 1% respectively (compared as percentage tracked tiles inside/percentage tracked tiles outside for each period and area, and using a paired *t* test and normalized data, $P = 0.8 - 0.9$).

Relatively low levels of damage occurred in all of the plots, but damage was greater in the plots surrounded by lethal barriers (average 2.05%) than in those surrounded by the non-lethal barriers (average 0.23%). Despite the small sample size (2 degrees of freedom), this difference almost achieves a level of statistical significance ($t = 2.0$; $P = 0.8 - 0.9$) when compared using a two-sided paired *t* analysis.

We attempted to repeat this study during the following rainy season, when rat intensity is usually greater, and when the comparative effectiveness of the fence designs would be better tested. During this trial, however, vandalism of the non-lethal fences became a chronic problem and prevented realistic comparison of the results. However, a number of observations which were made during this trial warrant comment. Two of the electric shockers malfunctioned during the period of this trial. Although both were repaired shortly after the problem was detected and so did not seriously hamper the performance of the fences, the malfunctions were both associated with transformer contacts within the shocker, and indicate that weather-proofed shockers may be required for long-term successful performance under the wet and humid conditions of Philippine ricefields. Despite the generally humid conditions of this wet season trial, batteries operating the non-lethal barriers only had to be recharged once or twice during the growing period. During several of the night observations, rats were seen attempting to burrow under both barriers types; subsequent daytime observations indicated the success of some so that additional alterations in the prototype fence design may be required.

We conclude that the non-lethal barriers provided comparable or better protection from rat damage than the lethal barriers during the dry season in the study plots, but that additional modifications of the prototype design may be required before the full benefits of the non-lethal electric barrier is realized. Assuming comparable levels of performance, the most striking observations are that the non-lethal fences operated effectively without the need of a night crew to remove electrocuted animals and without the need of daily battery recharges. Although electric barriers, generally following the lethal fence

design of IRRI as a model, are occassionally found in farmers' fields in the Philippines, additional modifications of the non-lethal concept using local materials may eventually provide the small farmer with an affordable alternative to chemical control for reduction of rat damage in his ricefields.

Acute Toxicity of Warfarin to Domestic Chickens

Introduction

Although anticoagulant rodenticides are generally considered safe for non-target species, we routinely encourage farmers to place stations containing bait in locations remote from livestock, and suggest that they confine domestic animals during periods of baiting or that they construct devices around the stations which prevent access of non-target animals to the bait. Nevertheless, we occassionally receive complaints from farmers who believe that the bait has killed their livestock -- usually domestic chickens (*Gallus gallus*).

To determine the potential hazard of warfarin to local domestic chickens, we performed two acute oral toxicity trials in which test animals were exposed to high levels of warfarin and observed for two weeks.

Materials and Methods

Two tests were successively conducted in which 16 broiler chicks (33-day old) were confined in a 1.5 X 1.5 X 1 m cage for two days before treatment, then exposed (by gavage) in groups of four to the following concentrations of warfarin: for the first test, 0, 25, 125, and 470 mg per kg body weight; for the second test, 0, 625, 705 and 1057 mg per kg body weight. The animals were maintained with broiler mash and water *ad libitum* during a 14-day observation period following gavage, and those alive after this period were considered survivors. Animals which died during the observation period were necropsied to determine the cause of death.

Results and Discussion

Four of the 32 fowl died during the period of observation; one in the control group, and one each in the groups dosed at 470, 625, and 705 mg per kg body weight (Table 11). Only two of these, one in the group dosed at 470 mg per kg body weight and the other in the group dosed at 705 mg per kg body weight, showed obvious signs of anticoagulant poisoning -- internal hemorrhage and inflammed livers. None of the fowls exposed to the 1057 mg per kg body weight level of warfarin died during the period of study.

Table 11. Acute oral toxicity of warfarin to 33-day old broiler chicks (unsexed). Four animals were used for each dosage level and 8 for controls.

Average weight of animals (g)	Dosage (mg/kg body weight)	No. died during 14 days
717.8	0	1
675.5	25	0
610.3	125	0
785	470	1*
700.2	625	1
753.5	705	1*
701	1057	0

* Results of necropsy indicated acute anticoagulant poisoning.

Based on these results, we conclude that the acute toxicity (expressed as lethal dose in which fifty percent of the population die) of warfarin to local domestic chickens is higher than the levels tested in the trials, but that response of individual chickens to the compound varies considerably. In order to receive a level of warfarin equivalent to 470 mg per kg body weight, the lowest dosage at which a fowl was affected during our trials, an animal would have to consume almost two kg of bait containing 0.025% warfarin (the concentration recommended for use in baiting programs); the probability that a chicken would consume this amount by accidental exposure is quite remote, and the probability that it would suffer acute effects if it did are also low. We conclude that the use of warfarin as recommended for reduction of rat damage to rice in the Philippines represents an extremely low hazard to local domestic chickens by accidental poisoning, providing the farmer follows the recommended baiting program and does not allow his fowl to eat treated bait as a substitute food source for extended periods of time.

Protection of Corn Crops from Rat Damage Using Sustained Baiting with Anticoagulant Rodenticides

Introduction

Sustained baiting with anticoagulant rodenticides has been used successfully to reduce rat damage in Philippine ricefields (Sanchez et al., 1972-1975). Corn is another important cereal crop grown in the Philippines and other Asian countries and, although actual losses have not been quantified, corn is frequently subjected to heavy rat damage. As with rice, traditional methods of control, when used, appear to have little effect in reducing rat damage. In 1975, we conducted a preliminary trial on the use of sustained baiting with anticoagulants to protect corn crops from rat damage. Despite generally low levels of damage, we concluded that the baiting program effectively reduced damage in the treated plots, with modest economic benefit for the farmer. A difficulty was encountered because the trial was conducted in the fields of small farmers, and differences in production inputs (such as fertilizer) made it difficult to isolate the actual benefits of the control program to the farmers.

The trial reported here was conducted within a large, mechanized corn plantation so that production inputs, other than rat control, were almost identical for each of the study plots. The experimental design was similar to that of the 1975 study, except that baiting was delayed until five weeks after the corn had been planted.

Materials and Methods

Six 2-hectare plots (A-F), separated by at least 200 meters, were selected within a 35 hectare portion of the Don Carlos Corn Project, a 400 hectare project located in Bukidnon, Mindanao. The study site was surrounded by a forest and creek on three sides and uncultivated shrub area on the fourth side. Plots A-D were closest to the forested sides, while Plots E and F were located near the shrub area. All plots were separated from uncultivated vegetation by at least 50 meters. Managers for the project had reported heavy rat damage in the past in this area and agreed to cooperate fully with the study. Three plots (A, C, E) were selected for treatment while the remaining three (B, D, F) were designated as reference plots.

In each of the treated plots, six points (one in each of the corners and one at the midpoint of the two longest sides) were arbitrarily chosen for baiting. Four bait stations, constructed from coconut husk

with bamboo (see Sanchez et al., 1974, p. 93), were initially placed at each baiting point and filled with 200 grams of 0.025% warfarin treated rice shorts (binlid; both low quality rice and corn were used as bait during the study). Baiting was initiated on the sixth week after planting and continued until harvest. Stations were checked 2-3 times weekly, number of stations and amounts of bait added were adjusted to maintain a slight excess over consumption, and amounts of bait added weekly were recorded. No rodenticides were used in reference plots.

In each of the plots, data were also collected on species composition, levels of rat activity, and extent of damage. Species composition was determined by snap trapping with 25 traps per plot for two consecutive nights prior to baiting in the treated plots. Rat activity was determined with tracking tiles before treatment and at 8 and 11 weeks after planting. Twenty-four tracking tiles, placed in three transects with 10 tiles each at about 25-meter intervals, were used in each plot for 3 consecutive nights. Relative levels of activity were based on numbers of positive (rat-tracked) tiles.

Damage appraisals were conducted within 2 weeks of harvest. Since each plot consisted of 133 rows that were 200 meters long, ten rows were randomly selected and ten samples (each consisting of one meter and eight plants) were taken for each selected row, or a total of 100 samples (800 plants) for each plot. For each sample, the number of plants having ears with rat damage was recorded. Because plots were equal in size, the same sampling sequence was used in each plot.

Records were maintained by the project managers of all production investments made during the growing season. Other than yields, these records were not available at the time of preparation of this report, but they will be analyzed and presented in the final report on this study.

Results

A total of 29 animals were collected during the 2 nights of trapping (250 trap nights) before treatment, or about an 11.6% trap success. Seventeen were taken from the treated plots, 12 from the reference plots. In treated plots, R. r. mindanensis was most common (59%), followed by R. exulans (24%), S. murinus (12%), and R. argentiventer (6%). In reference plots, R. r. mindanensis was also most common (75%), followed by R. exulans (17%) and R. argentiventer (8%). No S. murinus were collected in the reference plots.

Bait and bait stations were added at baiting points in the treated plots as dictated by consumption, so we assume that records of bait additions closely approximate actual consumption. As shown in Table 12, actual consumption was greatest during the first week of baiting (the sixth week after planting) when an average of 4.8 kg of bait was added in each of the treated plots. Consumption then declined for one week, increased gradually for three weeks, and dropped rapidly to zero by the eleventh week after harvest. After the initial surge of bait consumption (when an average of 200 g of bait was taken from each of the stations), numbers of stations were adjusted to maintain an average of 138 grams or less consumption per station per week. Total bait additions for the three treated plots averaged 16.6 kg, was highest in Plot A (19.8 kg), and lowest in Plot C (14.7 kg).

Based on tracking tile data, treated and reference plots had similar levels of rat activity before baiting (Figure 12). In reference plots, activity remained about the same as the cropping season progressed, while it decreased rapidly in the treated plots. By the 8th week after planting, rat activity in the treated plots was considerably lower than in the reference plots (average 3.0% vs 16.7%, respectively); the difference was even more pronounced by the 11th week after planting (average 0% vs 16.3%, respectively).

Eight hundred (0.38%) hills in each plot were sampled for rat damage within 1 week of harvest. Damage was considerably lower in the treated than in the reference plots, 0.86% vs 5.4% respectively. Assuming that our samples were typical for each of the plots, about 11,500 hills per plot were damaged in the reference plots compared to an average of 1,830 in the treated plots, a difference of about 9,670 hills per two hectare plot, or a damage reduction of about 84%.

We estimate that the cost for rat control in the treated plots ranged from ₱28.50-₱32.40 per hectare and averaged about ₱30. These estimates are based on the cost for preparation and use of 7.35-9.9 kg of bait per hectare at ₱1.50 per kg, and on the average time for maintenance of baits stations of 2.5 hours per week per hectare at a labor cost of ₱1.00 per hour.

Harvests in the treated plots averaged 77.7 cavans per hectare while those in the reference plots averaged 73.3 cavans per hectare, a difference of 4.4 cavans per hectare. The corn was sold at a standard price of ₱50 per cavan, so that corn in the treated plots had a gross value which averaged ₱220 per hectare more than the average for the reference plots.

Table 12. Average numbers of bait stations and amounts of bait used in three two-hectare cornfields employing sustained baiting with chronic toxicants at Don Carlos Corn Project, Bukidnon, Mindanao.

Weeks After Planting	Average No. of Stations/Plot	Bait Added (Weekly)	
		Total (kg/plot)	Mean (g/station)
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	24	4.8	200
7	24	3.3	138
8	26	3.6	138
9	32	4.4	138
10	24	0.6	25
11	12	0	0
12	6	0	0

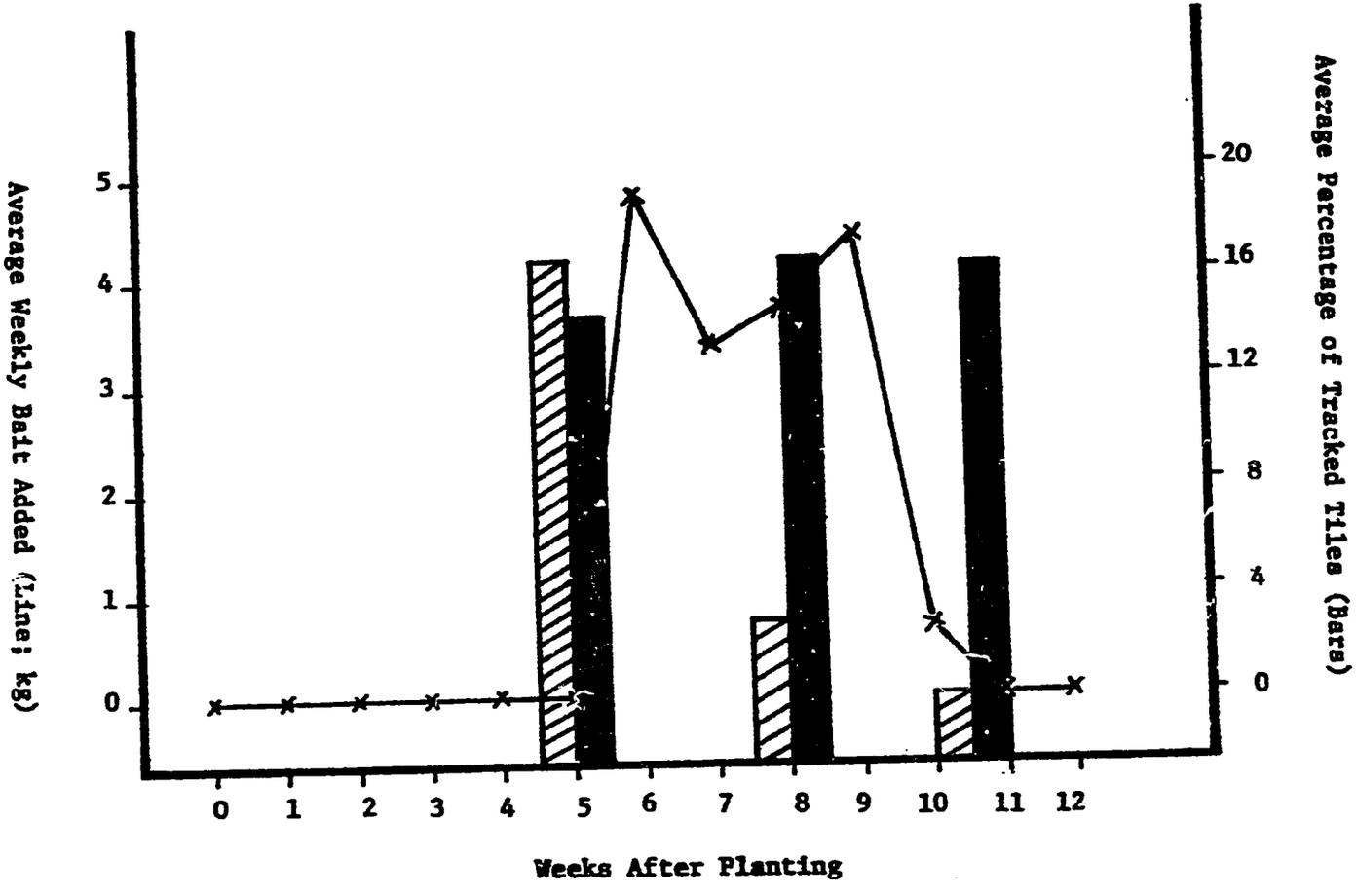

Figure 12. Rat activity in three treated and three reference corn plots, and bait used (average weekly, kg/plot) in the treated plots. Plots were 2 hectares each and located near Bukidnon, Mindanao. Rat activity is based on the average percentage of tracked tiles which were placed in the plots at three week intervals for three consecutive nights.

Discussion

Bait consumption and rat activity generally followed the patterns that we have observed when sustained baiting is used in ricefields and in the previous trial in cornfields. The high level of consumption during the first week is of interest and may have been a result of delaying the baiting program until the fifth week after planting. Total costs for the labor required to maintain the stations (estimated at ₱5 per hectare per week and over one-half of the total program costs) were reduced considerably, but the effects on overall bait consumption and effectiveness of the control program are unknown and require additional study. On small farms the costs for labor can sometimes be disregarded because the farmer does the work himself and in combination with other farming activities. Thus, the period of baiting may not be a critical factor in determining program costs at the small farm level.

Yields in the reference plots averaged 73.3 cavans per hectare, 4.4 cavans less (or about 5.7%) than in the treated plots. Likewise, damage in the reference plots averaged 5.4% while it was less than 1% in the treated plots. Because all other production factors were kept the same within the experimental plots, we suggest that the difference in yields was a consequence of the sustained baiting program.

Additional work is required before a refined statement of economic benefit can be presented. At a market value of ₱50 per cavan, corn produced in the treated plot was worth about ₱220 more per hectare than in the reference plots. With an average cost of control of about ₱30 per hectare, we estimate a cost to benefit of about 1/7. Since these estimates assume complete loss of ears on damaged plants (which was frequently the case), the cost to benefit would be lower if some ears on damage plants could be harvested. In contrast, the cost to benefit would be considerably higher in the fields of small farmers where the costs for maintenance and operation of the bait stations are lower.

We conclude from this study that sustained baiting with anticoagulants effectively reduced damage in the treated corn plots. Additional studies are required to obtain more refined information on the economic benefits of the program, but our preliminary analysis, based on this study, is that the baiting procedure provides considerable potential for good economic return, particularly when applied at the small farm level.

Assessing Rat Damage to Corn

Introduction

At least two methods are required for the complete assessment of direct losses to rodents in cornfields: one, a sampling method, is use to determine the proportion of ears having at least some damage in the field; the other, usually based on a known relationship between corn weight and a parameter of damage, is used to determine the extent of loss on damaged ears. In situations where partial damage to an ear of corn means complete loss of the ear (for example, when sweet corn is grown for sale in commercial markets), only the sampling method may be required for a reliable estimate of economic loss. In many situations in the Philippines, however, partially damaged ears are used for various purposes (such as animal feed), so that reliable estimates of economic loss (and consequently, economic benefit of potential control programs) require both methods.

Stone et al., (1972-1973) have suggested sampling methods for surveying bird damage to corn in the field, and we have used methods similar to theirs for estimating the proportion of ears receiving rat damage in the Philippines. A major problem is that the reliability of these methods depends upon the distributional patterns of rat damage in the cornfields, a factor which had not been investigated carefully in the Philippines, so that the reliability of the sampling methods are essentially unknown.

De Grazio et al., (1969) have developed a method for predicting weight loss caused by blackbird damage to individual ears of corn, and we have modified this method for use with rat damage in the Philippines (Sanchez et al., 1975). The method has two major problems, however: it is based on the relationship between weight of corn loss and length of damage, which is heavily influenced by the total length of ear, and requires several equations for reliable prediction of corn loss if ears of different lengths are considered; and, for use with rat damage in the Philippines, the damage patterns of sampled ears must be described as eigher "strip-type" or "circular-type" (each has its own sets of regression equations) -- many of the actual damage patterns which we observe in the field fit neither type.

We report here the preliminary results of two approaches to the development of a simple and reliable method for assessing rat damage to corn in the Philippines. In the first, we use distributional maps of rat damage in cornfields to determine the reliability of potential

sampling methods. In the second, we investigate the relationship between kernel weight and area occupied on ears of corn to determine if this relationship might serve as the basis for a simple, reliable means of predicting corn loss to rat damage.

The Reliability of Potential Sampling Methods

Materials and Methods

Two fields within two weeks of harvest were selected: one at the Lanese Experimental Area in Misamis Oriental; the other owned by a farmer near San Isidro, Agusan Sur. The first field, approximately 0.15 hectare, was surrounded by grasses and weeds on two sides and an uncultivated ricefield and a cornfield on the other sides, and appeared to be severely infested by rats. The second field, approximately 0.35 hectare, was surrounded on three sides by other cornfields at the same stage of development and on the fourth side by a weedy river embankment, and appeared to have a low level of rat infestation. The fields were planted with the same corn variety, BPI DMR-1. In each field, we counted the numbers of rows and the number of hills of corn plants in each row (columns). We then examined the ears of corn on each hill and recorded the hills (rows and columns) with rat damage. We used this data to develop a distributional map of hills with rat damage for each of the fields.

Using the maps as models, we simulated three types of sampling methods for the assessment of the proportion of hills having rat damage. With each test and method, we sampled about 5% of the hills. For the first sampling method (random), we randomly selected about 1% of the hills in the field, and "examined" the selected hill plus the next four in that column for rat damage. For the second sampling method (systematic), we randomly selected a hill within the field as a starting point. From the starting point, we alternately "examined" five hills in the column, skipped five, "examined" five, etc, and sampled every tenth row, so that a total of 5% of ten hills were "examined" and the pattern of examination was uniformly distributed throughout the field. For the third sampling method (random-clumped), we randomly selected 0.2% of the hills in the fields, then "examined" all the hills within a five row by five column area (25 hills), using the selected hill as the one within the sampling area which has the lowest row and column number; again, a total of about 5% of the hills were "examined" for each test with this method. We simulated each method on the maps five times for a total of thirty tests. For each test, we estimated the proportion of damage as follows:

$$\text{hills damaged (percentage)} = \frac{\text{hills "examined" with damage}}{\text{total hills "examined"}} \times 100$$

Results and Discussion

The field at the Lanese Experimental Area had a total of 5952 hills, of which 895 (15.04%) had rat damage. The field near San Isidro had a total of 12,853 hills, of which 624 (4.85%) had rat damage. Distribution of rat damage within the fields appeared influenced by proximity to uncultivated adjacent areas, and hills with damage were frequently clumped together (Tables 13-14).

Of the sampling methods tested, the systematic method had the lowest variability, but the random method appeared most accurate (Table 15). The random-clumped method was both most variable and least accurate, perhaps because it required fewer samples to examine 5% of the population. The random method overestimated damage slightly (0.7% and 3.5%) in both fields, while the systematic method overestimated damage (16.7%) in the field with a higher level of damage, and underestimated damage (8.4%) in the other field.

While additional studies are required to determine which of these methods, or modifications of them, will provide the best results with the least effort in the field, the use of distributional maps as models on which potential sampling methods could be simulated provided a relatively quick and sensitive means of comparing the reliability of each of the sampling methods, and appears to be a useful tool for the development of assessment methods for vertebrate damage in a variety of crops.

Relationship Between Kernel Weight and Area Occupied on Ears of Corn

Materials and Methods

Sample ears (40) of mature, field-dried corn of various sizes were randomly picked at harvest from ears having rat damage in a seven hectare cornfield near Barcinaga, Mindoro, and brought to the laboratory for study.

Each ear was husked, numbered, wrapped tightly with a sheet of carbon paper and tracing paper, and rubbed thoroughly with a pencil. The tracing

Table 13. Distribution of hills with ears damaged by rats at harvest in a 0.15 hectare cornfield (variety BPI-DMR-1) at the Lanese Experimental Area, Misamis Oriental. The field was surrounded by uncultivated areas. Numbers in parentheses represent total hills within incomplete blocks -- all other blocks contain 25 hills. Of 5952 hills in this plot, 895 (15.04%) had damaged ears.

Columns/Rows	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61
101	-	-	-	2(4)	2(5)	0(5)	1(5)	3(5)	1(3)	-	-	-	-
96-100	1(1)	9(11)	7(22)	4	10	2	5	4	13	1(3)	-	-	-
91- 95	17	4	3	0	2	4	3	1	8	9	6(15)	0(1)	-
86- 90	5	5	7	0	0	0	4	0	7	1	9	7(14)	-
81- 85	2	2	2	0	0	2	9	1	1	7	7	8	2(3)
76- 80	8	2	1	1	4	7	11	1	5	4	2	6	3(5)
71- 75	5	1	0	3	0	2	1	0	1	8	4	2	3(5)
66- 70	5	9	2	0	1	2	0	6	2	0	2	1	1(5)
61- 65	5	2	4	0	0	3	4	0	3	6	2	6	1(5)
56- 60	2	0	2	1	3	0	1	4	3	7	2	6	2(5)
51- 55	1	3	1	1	2	3	1	0	0	0	0	0	1(5)
46- 50	7	2	2	3	2	2	1	5	1	3	2	3	1(5)
41- 45	3	0	3	1	2	0	2	1	3	0	4	4	3(5)
36- 40	1	2	9	8	4	0	9	4	5	4	1	3	1(5)
31- 35	4	8	0	2	3	11	2	3	7	5	2	4	1(5)
26- 30	6	1	7	9	0	2	4	3	5	3	2	4	2(5)
21- 25	4	7	1	4	4	4	9	3	5	5	5	10	2(5)
16- 20	8	8	3	4	6	2	4	3	3	8	4	2	3(5)
11- 15	4	3	5	0	2	1	3	3	4	3	3	5	1(5)
6- 10	4	4	2	6	2	4	8	1	8	1	1	3	1(5)
1- 5	2	7	6	9	7	2	4	9	5	3	11	6	2(5)

Table 14. Distribution of hills with ears damaged by rats at harvest in a 0.35 hectare cornfield (variety BPI DMR-1) near San Isidro, Agusan Sur. The field was adjacent to other cornfields on three sides and to a shrubby area on the fourth (left side below). Numbers in parentheses represent total hills within incomplete blocks — all other blocks contain 25 hills. Of 12,853 hills, 624(4.85%) had damaged ears.

Columns/Rows	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100	101-105	106-110	111-115
116-120	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-
111-115	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0(5)	-	-
106-110	6	4	1	5	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0(6)	-	-
101-105	2	3	0	0	7	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0(10)	-	-
96-100	1	0	0	2	2	5	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0(13)	-	-
91- 95	6	2	0	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0(15)	-	-
86- 90	1	1	2	2	0	0	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0(19)	-	-
81- 85	6	0	2	1	1	0	6	0	0	1	1	1	3	5	0	0	0	0	0	0	0(20)	-	-
76- 80	3	3	0	0	0	0	0	4	1	0	7	1	0	0	1	0	0	0	0	0	0(25)	-	-
71- 75	8	1	5	3	7	2	0	0	0	0	0	8	7	1	1	0	0	0	0	0	0	0(1)	-
66- 70	3	1	0	0	0	1	3	2	0	0	0	0	0	0	1	1	6	0	0	0	0	0(5)	-
61- 65	0	2	1	4	0	0	0	1	0	0	1	1	0	4	2	2	0	1	1	0	0	0(7)	-
56- 60	2	1	6	2	0	1	2	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0(10)	-
51- 55	1	7	3	1	0	0	0	3	1	5	2	0	11	6	5	3	3	0	0	0	0	0(15)	-
46- 50	7	3	0	0	0	0	0	4	5	3	3	8	0	2	11	0	0	0	0	0	0	0(18)	-
41- 45	0	0	0	0	0	5	0	4	0	4	4	2	0	0	0	0	1	1	0	0	0	0(20)	-
36- 40	0	0	0	0	5	6	0	4	2	0	1	0	0	5	5	3	3	1	0	0	0	0(23)	-
31- 35	5	0	0	0	1	0	0	0	0	0	4	0	0	7	3	0	0	0	0	0	0	0(25)	-
26- 30	2	4	0	5	0	0	0	2	0	6	1	2	11	3	0	0	1	0	0	0	0	0	0(5)
21- 25	4	3	1	0	2	1	0	0	0	1	0	6	0	1	0	1	1	0	1	0	0	0	0(7)
16- 20	4	3	2	1	6	0	2	0	0	3	4	1	0	10	0	2	0	1	2	0	0	0	0(10)
11 15	6	1	7	1	2	0	8	0	2	1	0	0	1	12	1	0	1	1	1	0	0	0	0(14)
6 10	3	3	0	2	3	0	2	0	1	2	0	4	9	0	1	2	1	0	0	0	0	0	0(15)
1- 5	6	6	4	8	3	1	4	0	2	1	1	6	0	1	1	1	0	0	0	0	0	0	0(20)

Table 15. Results of three sampling methods for the estimation of rat damage in cornfields. Methods, based on about 5% of the hills, were simulated on distribution maps of damaged hills in two cornfields.

	Sampling Method		
	Random	Systematic	Random-Clumped
Field A*			
No. Samples/Test	60	60	12
No. Tests	5	5	5
Estimated Damage (%):			
Mean	14.93	12.53	11.80
Range	(12.3-18.0)	(11.0-14.7)	(4.0-17.3)
Std. Error of Mean	1.11	0.63	2.20
Actual Damage (%)	15.0	15.0	15.0
Error (%)**	0.7	16.7	21.5
Field B***			
No. Samples/Test	130	130	26
No. Tests	5	5	5
Estimated Damage (%):			
Mean	5.01	5.26	7.45
Range	(3.4-7.2)	(4.8-6.0)	(4.2-10.0)
Std. Error of Mean	0.65	0.20	1.03
Actual Damage (%)	4.85	4.85	4.85
Error (%)**	3.3	8.4	54

* 0.15 hectare, variety BPI DMR-1, at the Lanese Experimental Station, Misamis Oriental

** Error = (Mean Estimated Damage - Actual Damage) ÷ Actual Damage x 100

*** 0.25 hectare, variety BPI DMR-1, near San Isidro, Agusan Sur

paper, when removed, had dark, rectangular impressions in columns which corresponded to kernels on the ear (undamaged area), and light areas where rat damage had occurred. Profiles of these areas were traced on graph paper (0.01 square inch), labeled damaged or undamaged, and numbered to correspond with the ear. The ear was then shelled, and the kernels weighed (weights obtained were not adjusted to 14% water content for this preliminary study).

The following measurements were obtained from each of the profiles: greatest length (with kernels) of ear (mm), greatest length of damage (mm), greatest width of damage (mm), and total and damaged areas (square inches). Measurements of area were made by using a compensating polar planimeter with the tracer arm adjusted to read in 0.01 square inches; perimeters were traced three times and the average used as the measurement. For ten of the samples, randomly selected, areas were also determined by counting blocks (0.01 square inch) on the graph paper within the profiles. The undamaged area of an ear was obtained by subtracting the damaged area from the total area.

Results and Discussion

The greatest length (with kernels) of ears ranged from 55 mm to 148 mm and the total surface area from 7.85 square inches to 25.55 square inches (Table 16); thus, the sample included ears with about a threefold variation in size. Likewise, as indicated by measurements of greatest length, width and area, damage varied from negligible to almost complete loss of kernels among the ears included in the sample. Damage patterns also varied considerably, but always appeared to originate near the apex of the ear. We would have found it difficult to classify most of these patterns as either "strip-type" or "circular-type"; profiles of damage were quite irregular and most seemed to have some attributes of both types.

To determine our skill in using the planimeter, we compared (by simple linear regression) total and damaged areas obtained by using the planimeter for ten of the samples with results obtained by counting squares within profiles for the same areas. For both total and damaged areas, results of the two methods were highly correlated (for damaged area, $t = 63$; for total area, $t = 47$; for both, $r > .998$, $P_r << 0.001$). Slopes for the regression equations relating the squares method ($\underline{X}$) to the planimeter method ($\underline{Y}$) were 0.988 and 1.022 for damaged area and total area respectively, indicating that the planimeter was calibrated and operating correctly.

Table 16. Measurements of rat damage to 40 ears of yellow corn randomly selected from those damaged at harvest in a seven hectare field near Barcinaga, Mindoro, June 1976.

Measurement	Mean	Standard Error of Mean	Range
Greatest Length (with Kernels) of Ear (mm)	103.6	12.1	55-148
Greatest Length of Damage (mm)	67.7	19.6	18-117
Greatest Width of Damage (mm)	49.2	9.6	13-93
Weight of Undamaged Corn (g)	30.1	10.0	3-77
Surface Area (0.01 sq. in.)*			
Total	1598	6675	785-2555
Damaged	428	2087	68-1140
Undamaged	1170	8761	182-2444

* Areas were transferred from ears to paper by wrapping carbon paper and tracing paper around ears and rubbing with a pencil. Outlines of damaged and total surface were transferred to graph paper: each surface was measured three times for each ear using a compensating polar planimeter (with tracer arm adjusted to read in 0.01 square inches) and average readings were used as measurements. Undamaged area was obtained by subtracting total area from damaged area.

Since the weight loss of corn from damaged ears was unknown, we tested the relationship between area of undamaged corn and its weight. As shown in Figure 13, these are highly correlated ($r = 0.96$; $P_r \ll 0.001$) with the relationship described by a single linear equation, $\underline{Y} = 0.032(\underline{X}) - 7.94$ where $\underline{Y}$ is the weight of undamaged corn (grams) and $\underline{X}$ is the undamaged area of the cob in square inches. We note that this relationship was derived from actual field samples having irregular patterns of damage (and, conversely, of non-damaged areas), without the need for separating patterns of damage into types, and without the need for developing separate regression equations for different categories of cob length.

We also note, however, that three curves which deviate from this relationship can be detected in Figure 13. These are most obvious with the higher areas and greater weights of corn, and apparently correspond to different total ear sizes. The deviation is relatively small, however, so that simple linear regression can still be used to accurately describe the relationship between area and weight of undamaged corn for the population of ears.

We conclude that area of damage, irregardless of its pattern, can be easily measured by use of tracing paper and a compensating polar planimeter, that the relationship between area of damage and corn loss (weight) may be less affected by ear length than the relationship between length of damage and corn loss (weight), and that additional, more detailed studies are warranted.

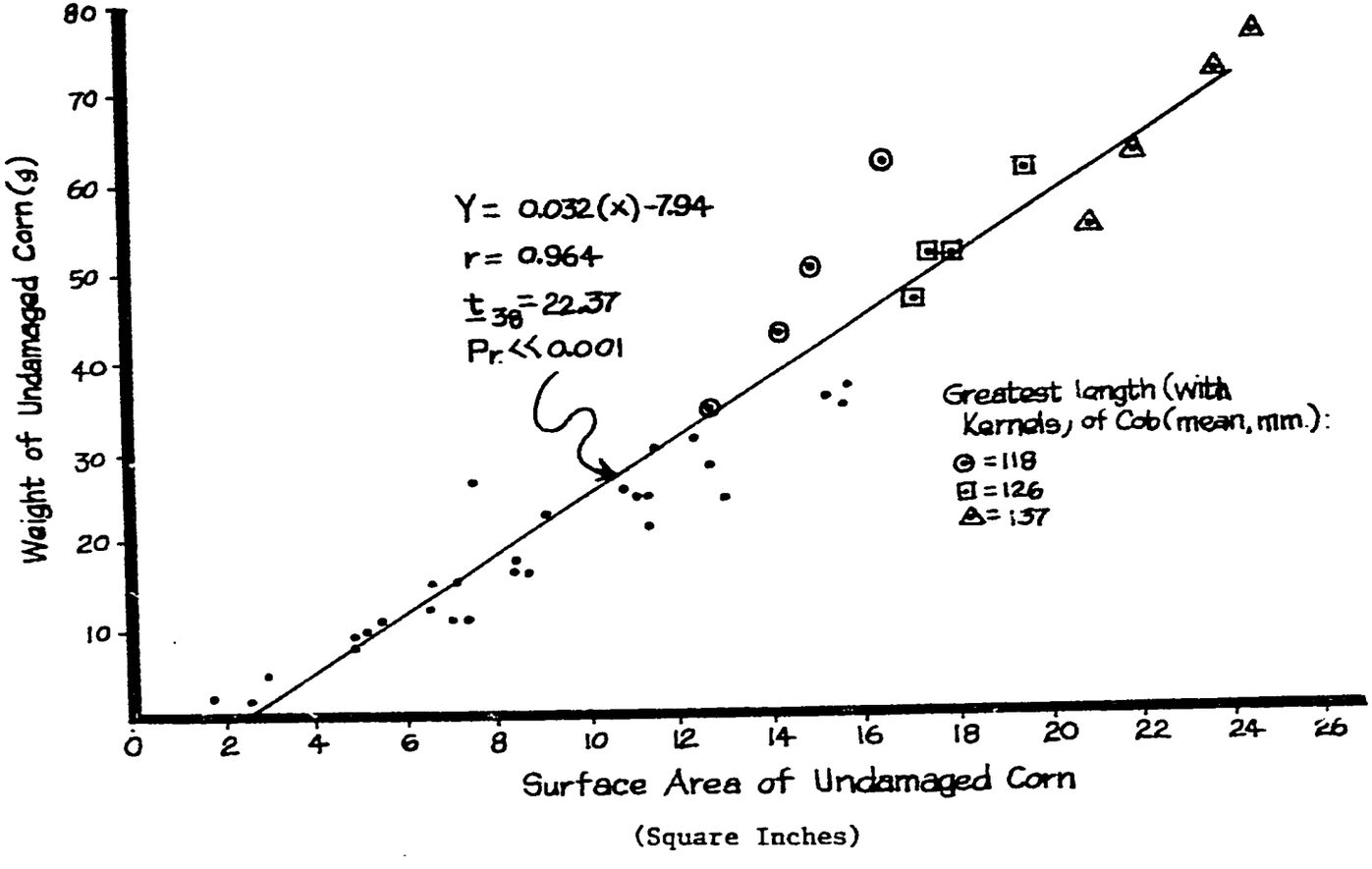

Figure 13. The relationship between weight of undamaged corn and area occuppied on ears which had rat damage in a seven hectare cornfield near Barcinaga, Mindoro.

Biological and Toxicological Studies on Philippine Pest Bird Species

Introduction

Feeding behavior and damage potential of three Philippine bird pests have already been reported (Alviola et al., 1973; Benigno et al., 1975). Preliminary results of toxicological studies and initial field trials on the use of methyl carbamate and fenthion as bird repellents were reported last year (Sanchez et al., 1975). These trials were continued during the current year, additional observations were made on the damage behavior of pest species and the reproductive behavior of Lonchura malacca, and initial toxicological studies were conducted on methamidophos (0,5-dimethyl phosphoro-midothiate), an insecticide which has been observed to kill Passer montanus when it feeds on worms from cabbage plants treated with the compound.

Materials and Methods

For the trial on the use of methyl carbamate and fenthion as repellents, six plots (each 5m X 10m and separated by at least 20m) were located within a two hectare ricefield at three weeks before harvest in Baco, Mindoro Oriental. Plots were randomly assigned treatments: two were sprayed with methyl carbamate (4.7 kg active ingredient per hectare in water); two were sprayed with fenthion (0.9 gallon containing 50% emulsifiable concentrate per hectare); and, two were left untreated. One hundred hills were randomly selected within each plot and examined for damage 14 days after treatment; hills were recorded as either damaged or not damaged.

For further observations on the damage patterns of pest species, four study plots (each 2m x 14m and seperated by 0.3m dikes) were selected in an experimental ricefield of the University of the Philippines at Los Baños. Hills were examined for bird damage at hard dough stage of development. For each plot, 46 randomly selected hills were examined: 10 each in four rows (2 edge rows and 2 interior rows) of hills and 6 each in two widths (edges) of the plots. Hills examined were recorded as either having or not having bird damage. A later attempt to protect these plots with methiocarb was foiled by heavy rains five hours after spraying which diluted the concentration of repellent and by disappearance of the pest birds shortly before treatment.

To obtain some information on the reproductive behavior of birds, a 0.5 hectare calamansi orchard with 300 trees, located in Barcinaga,

Mindoro Oriental, was visited monthly for eleven consecutive months. On each visit, the number of nests, nests with eggs, and hatched young were recorded. The data obtained was used to determine the breeding season for L. malacca, which has used this orchard as a breeding site in the past.

The acute oral toxicities of methamidophos to three Lonchura species and P. montanus were determined and compared with those of carbofuran. Procedures used for the toxicity trials have already been described (Sanchez et al., 1974).

Results and Discussion

Plots treated with methyl carbamate and fenthion averaged 6.5% and 7.0% damaged hills respectively, while the two untreated plots averaged 22% damaged hills. This indicates that both compounds hold promise of reducing crop losses to bird pests, but additional, more detailed trials involving larger areas and bird counts are required to assure the validity of the results.

In the ricefield plots observed at the University of the Philippines at Los Banos, significantly more hills were damaged along the width (edges) of the plots than along the rows (either along the edges or within the plots; Table 17). This data indicates a behavioral preference of birds for feeding along the short edges of the experimental plots, but additional studies are required to see if this preference is maintained in the fields of farmers. We also observed, but were unable to quantify, that damage distribution appeared to vary with the density of plants: the lower the density, the greater the likelihood for a random distribution of bird damage throughout the plots; the greater the density, the greater the likelihood that birds would congregate near the edge of plots and damage only the peripheral plants. In most situations, birds seemed to prefer the tallest panicles in a hill which contained milky or maturing grains. L. punctulata, L. malacca, L. leucogaster and P. montanus were all observed damaging grains in these plots.

As shown in Table 18, nests for L. malacca were observed from February through May and from July through October in the calumansi orchard in Mindoro Oriental. Young were observed in the nests during two times of the year: March and April, and August through October (trees were pruned in September and no nests were observed). This indicates that L. malacca may have a bimodal annual breeding season at this study site, in contrast to L. punctulata on Luzon, where a single nesting peak was observed in April and a peak of young followed three months later, in July (Sanchez et al., 1974). Additional studies are required to verify these findings.

Table 17. Percentage of hills having damage in four study plots in an experimental ricefield at the University of the Philippines at Los Baños. Two rows (lengths) were sampled along the edges and two within each experimental plot, as well as the plants along the width (edges only).

	Outside Rows		Inside Rows		Width (Edges)	
	Actual (%)	(Transformed)*	Actual (%)	(Transformed)	Actual (%)	(Transformed)
Plot I	40	(39.23)	20	(26.57)	83	(65.65)
Plot II	50	(45.00)	45	(42.13)	100	(90.00)
Plot III	50	(45.00)	50	(45.00)	100	(90.00)
Plot IV	35	(36.27)	10	(18.43)	100	(90.00)
Mean	43.8[b]	(41.38)	31.2[b]	(33.03)	95.2[a]	(83.91)

* Figures in the parentheses are the arcsine transformed values. Means were compared by Honestly Significant Difference; those having different superscripts are significantly different at the 1% level.

Table 18. Reproductive data for *L. malacca* in a 0.5 hectare calamansi orchard in Barcinaga, Mindoro Oriental. Figures in parenthesis are ranges for numbers of eggs or young in individual nests.

Months	No. of trees with nests	No. of new nests	Total No. of eggs	Total No. of young
January	0	0	0	0
February	3	3	9 (1-4)	0
March	2	2	10 (0-5)	1 (0-1)
April	3	4	6 (0-5)	3 (0-3)
May	1	1	0	0
June	0	0	0	0
July	2	2	2 (1)	0
August	3	3	5 (0-4)	2 (0-2)
September	(Trees	Pruned		)
October	4	4	5 (1-4)	3 (1-2)
November	0	0	0	0

The acute oral toxicity of methamidophos of pest birds is presented in Table 19: it appears most toxic to L. punctulata and considerably less toxic to the other species tested. Except for L. punctulata, the compound appears much less toxic to pest species than carbofuran.

Table 19. LD_{50} values (mg/kg) of carbofuran and methamidophos on four pest bird species. Figures in parentheses are the 95% confidence limits.

Species	Chemical	
	Carbofuran	Methamidophos
Lonchura punctulata	0.49 (0.37-0.66)	0.34 (0.25-0.46)
L. leucogastra	0.32 (0.28-0.40)	3.98 (2.92-5.43)
L. malacca	0.26 (0.22-0.35)	3.21 (2.26-4.45)
Passer montanus	0.38 (0.32-0.45)	5.40 (3.73-7.82)

Arriving in flocks during the early milk to maturing stages, pest birds sometimes cause extensive damage to ricefields in the Philippines.

TRAINING ACTIVITIES

TRAINING ACTIVITIES

Introduction

The Center has been increasingly active in training and extension within recent years. During this year, staff members provided resource lectures, laboratories or demonstrations on rodent control to over 3000 government extension personnel and key farmers from the Philippines and other countries. In addition, more than 300 visitors from many countries were briefed on the Center's activities, given technical assistance in the form of literature on rodent control, or advice in program planning. Numerous request for technical information on rodent control were filled with Center publications or copies of appropriate material from our library.

Workshops and In-Service Training

In support of the Philippine Governments' intensified food production programs -- Masagana 99, Masaganang Maisan, and Multiple Cropping, short courses on rice and corn production were again offered at UPLB and IRRI. Two-week courses on multiple cropping were again conducted by the Department of Agronomy, UPLB. These courses were aimed at updating the knowledge of technicians on the methods and skills in crop management practices and to present the principles of agricultural extension, farmer cooperatives, and supervised farm credit. The workshops offered opportunities for center staff members to present current information on rodent biology and control. During these lecture-discussions, emphasis was placed on mechanics and application of sustained baiting with anticoagulants. Technicians from the Bureau of Plant Industry (BPI), Bureau of Agricultural Extension (BAE), and other government agencies were involved.

Center staff members again presented lectures on vertebrate pest control in several one-month Supervised Farm Credit Courses involving Philippine National Bank (PNB) and Agricultural Credit Administration (ACA) loan officers. These courses were conducted under the auspices of the Agricultural Credit and Cooperative Institute. Some staff members also presented lectures on rodent control during in-service training programs sponsored by the Farm Systems and Development Corporation, and in programs sponsored by NFAC for outstanding farmers. About 40 technicians of the Philippine Sugar Institute (PHILSUGIN) were trained by Center staff in damage assessment methodology during a special seminar which was sponsored by PHILSUGIN. More than 100 students who took Crop Protection Courses visited the Center and were briefed on its current activities.

In support of the National Rat Control Program for Masagana-99 and Non-Masagana 99-covered areas, 2 day workshops on vertebrate pest management were conducted at the Rodent Research Center and in selected places in the different regions of the Philippines. Center staff served as a major resource during the workshops which involved Production Technicians of the BPI, BAE and regional rat control officers of the BPI. Lectures on the principles and practices of rat control, population biology and ecology, sustained baiting program, massive rat control operations and data monitoring were presented to the participants.

International Training

Participatory research training was initiated at the Rodent Research Center in late 1972. In this program trainees from Asian countries, depending on their background and objectives, spend from two to six months attached to the Center staff and participate in a variety of on-going research and evaluation activities, work independently on projects related to pest problems in their own countries, or develop work plans or project proposals for presentation to their parent agencies. Trainees are also given the opportunity to visit and observe related studies being conducted by other agencies and to visit operational rodent control programs in various parts of the Philippines. Participants in this program have received support from United Nations Development Programme Projects and USAID and from the governments of the Netherlands, Indonesia, Nepal, South Korea, South Vietnam, and Germany.

One trainee from Nigeria completed this program in 1976. Mr. Thaddeus A. Obadoni, a plant protection officer, arrived in late December (1975) and remained at the Center for almost three months, under the sponsorship of the Nigerian government and the International Institute of Tropical Agriculture, Ibadan, Nigeria.

Graduate Training

The opportunity for Master's degree work in vertebrate pest management is available through the University of the Philippines at Los Baños (UPLB). Scholarships, funded by the National Economic and Development Authority (NEDA) and developed through the cooperation of the Rodent Research Center Board, are available to provide support to qualified students. Additional support for book and research expenses is provided by the Bureau of Plant Industry. Graduate students have office space at the Center and make use of its facilities in conducting their research; senior staff members or other university faculty members may serve as graduate advisors. Under this program, six students have completed the requirements for the M.S. degree and six others have completed formal

coursework and are currently conducting their thesis research. The three M.S. graduates who joined the research staff of the Center are pursuing Ph.D. degrees in pest management, one under a PCARR Graduate Fellowship, the others with UPLB's reduced fee privilege. Another PCARR Graduate Fellow, from PHILSUGIN, completed his coursework and comprehensive examination during the year, and has begun research for his dissertation. Mr. Pablo Ocampo, USAID contract technician who joined the Center this year, began taking coursework which will lead to an M.S. degree in vertebrate biology.

Staff Instruction at UPLB

Several Center staff members hold joint appointments with departments of the University of the Philippines at Los Baños and act as graduate advisors or instructors. During this year, staff members taught or helped teach courses in Vertebrate Pests, Experimental Design, and Wildlife Management. Some sessions were held in the classroom and laboratories at the Center, and students used equipment and facilities located at the Center to conduct individual research projects. Several staff members assisted in the development of a science manual for use at the high school level in the Philippines.

Based on recent surveys conducted by Bureau of Plant Industry and Rodent Research Center staff, the rice terraces of Mountain Province were one of the rice-growing areas of the Philippines most severely affected by rat damage.

RESEARCH UTILIZATION

In early 1975, sustained baiting with anticoagulants, a method of reducing rat damage to rice crops that includes procedures and innovations developed and tested at the Center, was included as a required practice for farmers participating in the Government of the Philippines' national rice production program, Masagana-99. This program provides non-collateral loans of up to ₱1200 (ca. US $170) per hectare for the purchase of modern farming materials, including seeds, fertilizers, and pesticides. Each farmer works under the supervision of an agricultural technician to insure that the recommended practices are followed. Loans are repaid at each harvest and new loans are made for the next crop. Under the program, participating farmers can borrow up to about ₱50 (ca. US $7) per hectare for purchase of chronic rodenticides and materials for sustained baiting. In 1975, the procedure was also included as the major damage reduction method in the Philippine governments' national rat control program for non-Masagana-99 areas.

During 1976, major efforts were made to implement the sustained baiting procedure over wide areas of the country in three phases: continued training of extension personnel through in-service and short-term programs, and education of farmers in current methods through technicians and extension agents; use of acute toxicants in severely infested areas to reduce population levels; and, use of the sustained baiting approach over wide areas to reduce rat damage to the crops.

To evaluate the effectiveness of these rat control programs, and to obtain preliminary information on the requirements for an effective monitoring program, the Bureau of Plant Industry conducted damage surveys in six provinces of Central Luzon before and after implementation of the national programs. Each survey included 270 samples representing 84 barrios and 33 towns. Estimates of damage were based on the proportion of damaged tillers of the total in paddies that were sampled within two weeks of harvest.

As shown in Table 20, a dramatic drop in rat damage occurred following the introduction of the control programs in each of the areas, with an estimated average damage reduction of 98.5%. From this data alone, however, it is difficult to determine whether the reduced rat damage was the direct consequence of the control programs, a result of a normal variations in rat populations, or a combination of both. Future surveys for evaluation of the effectiveness of control programs should probably include samples from non-program areas, which could serve as a basis for judging normal variations

Table 20. Rat damage in six provinces of Central Luzon before and after implementation of national rat control programs.

Province	No. Locations Sampled		Average Damage (%)		Reduction in Loss (%)
	Towns	Barrios	Before	After	
Nueva Ecija	10	27	27.3	0.32	98.8
Bulacan	6	17	8.2	0.21	97.4
Pampanga	7	13	6.2	0.06	99.0
Bataan	4	9	5.2	0.11	97.9
Zambales	3	9	2.3	0.02	99.1
Tarlac	3	9	2.1	0.03	98.6
		Average	8.55	0.125	98.5

in levels of damage. Despite these problems, damage in program areas was greatly reduced and it appears that farmers who followed the control recommendations were able to successfully protect their crop from serious rat damage.

INTERNATIONAL ACTIVITIES

Director Sanchez was nominated as the invitational speaker for the 1976 Annual Meeting of the Entomological Society of America. The meeting was held in Honolulu, Hawaii, from November 29-December 3, 1976. In his keynote address, entitled "The Current Status of Rice Pest Management in the Philippines," Dr. Sanchez summarized the major vertebrate, insect, weed, and pathogenic pests which contribute to an estimated 35% reduction in yields annually in the country and described the traditional pest management practices of Filipino farmers. He emphasized the need for multidisciplinary, integrated pest management practices if gains of modern productive technology are to be realized, and described the efforts of the Philippine government to develop an institutional capability in crop protection.

Following this meeting, Dr. Sanchez attended a conference on the Impact of Pesticide Laws which was co-sponsored by the East-West Food Institute and the College of Tropical Agriculture of the University of Hawaii and held in Honolulu from December 6-10, 1976. Earlier in the year, January 5-9, 1976, Dr. Sanchez had attended a workshop, also held in Hawaii and co-sponsored by the East-West Food Institute and the University of Hawaii, on the Consolidation of Crop Protection Courses. At this workshop, he presented a paper entitled "Knowledge Needed by the Pest Management Specialist."

During his tenure as a participatory trainee at the Center, Mr. Thaddeus A. Obadoni, a Plant Protection Officer from Nigeria, learned techniques for collection, identification and necropsy of rodents, for measurement of rat activity in the field, and for evaluation of potential control methods. He also participated in several field evaluations of the sustained baiting method, in rice and in coconut, and developed a detailed proposal for research in vertebrate pest management to be submitted to his parent organization.

THE CENTER LIBRARY

In May, 1974, the Rodent Research Center established a small, specialized library which emphasizes the acquisition of current materials on vertebrate biology, ecology, and management. The library, now in its third year of operation, contains 716 books and pamphlets, 66 center publications, 872 reprints, 57 periodicals with a total of 1,019 volumes, 94 maps and more than 700 photographs and slides on vertebrates and their control.

The library is attended by a staff member. Permanent users are issued cards and loaned materials according to library policy. The library room is air-conditioned and has work space for persons who require only brief use of its resources. In addition to providing materials to local users, the library also fills requests for reprints or other technical information and maintains a mailing list for the Annual Report. This year, about 200 articles and over 350 Annual Reports were mailed to scientists, extension personnel and other libraries in the Philippines and many other countries of the world.

Newly established functions of the library include periodic literature searches on selected areas of vertebrate pest management; development of appropriate bibliographies, and distribution of content lists for journals that publish articles on vertebrate biology and control.

Rats in trees? This photograph was taken in an area with a localized rat outbreak -- rats were found climbing in a variety of trees during the daytime.

SUMMARY OF ACCOMPLISHMENTS

1. Full or part-time Center staff included five biologists, nine students, one biometrician, two field technicians, one trainee from Nigeria and eleven supporting staff.

2. A baiting program using anticoagulants to protect coconuts from rat damage was evaluated for two years in Mindoro Oriental where R. r. mindanensis, R. argentiventer, R. exulans, and S. murinus are found. Four plots, each one hectare with one hundred trees and separated by at least 200 meters, were chosen: during the first year, two plots were randomly selected for treatment and two designated as reference plots; during the second year, all plots were treated. During periods of treatment, a single packet of poisoned bait was placed in the fronds of twenty-five randomly selected trees per plot each month. By the third month after treatment, rat activity and numbers of fallen nuts had dropped to negligible levels in each of the plots and remained low thereafter, while rat activity and numbers of damaged nuts had remained high in reference plots during their one year without treatment. Production in the plots, during periods of treatment, increased about 2.5 times over pretreatment levels. Cost/benefit, based on actual costs for control and copra production, averaged 1/24. We concluded that sustained crown baiting has the potential of providing long-term reduction of coconut damage by rats.

3. A study was conducted in two, one hectare coconut plots (separated by 300 meters) to determine relative species composition and movement of rodents between tree crowns and the ground level. In one plot (A), packets containing polished rice and tetracycline hydrochloride (TC; a marking agent) were placed in the crowns of 50 randomly selected trees. In the other plot (B), the packets were placed at the ground level. After one week, packets were retrieved, the amount of bait consumed was determined, and trapping was conducted for three consecutive nights (at ground level in Plot A, at crown level in Plot B). Rats caught were identified and checked for presence of the marking agent. In Plot A, R. r. mindanensis, R. exulans and R. argentiventer were captured, but only R. r. mindanensis and R. exulans were marked; in Plot B, only R. r. mindanensis and R. exulans were taken and both species were marked). Bait consumption and trap success were lower in tree crowns than at the ground level.

Based on these results, we suggest that R. r. mindanensis and R. exulans moved actively between tree crowns and the ground level, but that relatively fewer individuals inhabited the tree crowns, and that movement of R. argentiventer from the ground level to the tree canopy was either severely restricted or absent.

4. Ground-baiting and crown-baiting were compared for relative effectiveness and economic benefit in a five hectare coconut plantation near Victoria, Mindoro Oriental. During the first 13 months of the study, bait stations containing anticoagulant rodenticices were placed near piles of litter at the ground level; during the next 12 months, one-fifth of the trees in the plantation were crown-baited monthly with packets containing anticoagulant rodenticides. Monthly records were maintained of the amounts of bait used, rat activity, and numbers of fallen nuts, and numbers of nuts harvested were recorded for each harvest period. Rat activity and numbers of fallen nuts were reduced by both methods, but were lower during the period of crown-baiting. More bait was used for the ground-baiting than the crown-baiting method (6 vs 1.5 kg per hectare per month, respectively), and more labor was required to maintain the baiting program (about 20 vs 12 hours/month, respectively). During a 22 month period prior to the study, coconut production averaged 2.9 nuts per tree per month; during the period of ground baiting, 5.8 nuts per tree per month; and, during the period of crown-baiting, 7.2 nuts per tree per month. We concluded that both ground-baiting and crown-baiting reduced rat activity and damage at our study site, but that crown-baiting was more effective and cost less, perhaps because it is more selective in reaching target organisms.

5. To determine if coconut trees can compensate for rat damage, we compared the sizes, weights, and copra contents of individual nuts (60, randomly selected during a single harvest) from an area which had received effective rodent control for twenty-one months with nuts (60, randomly selected during a single harvest) taken from an adjacent area which had no rodent control program and which was suffering from heavy rat damage. Wet weight of flesh averaged 0.86 kg per nut in the treated area, 0.050 kg (5.5%) less than in the area which had received no rat control. Likewise, dry weight of flesh (copra) in the treated area averaged 0.37 kg per nut, or 0.038 kg (9.4%) less than in the untreated area. When compared with larger samples taken over a longer period of time, however, differences were greatly reduced. We concluded that partial compensation by trees for heavy rat damage may have occurred in our experimental plots, but, if present, the amount of compensation was slight, insufficient for obvious separation from the fluctuation

of copra content over extended periods of measurement, and inadequate to decrease significantly the economic benefits which were gained by following the baiting programs.

6. The movements of rats in relation to rice culture were followed in a 1900 hectare ricefield area near San Antonio, Nueva Ecija, where planting and harvesting during the wet season follows recession of floodwaters. Bait stations containing polished rice with TC were placed in the first-planted fields at the vegetative stage, and trapping was conducted monthly in ricefields at vegetative to post-harvest stage for the next eleven months. Animals captured were examined for presence of the marking agent. In general, rats appeared to move in a directional manner out of harvested fields and into younger fields as the growing season for the study site progressed. This pattern was most apparent with adult rats, males moving the greatest distances -- two marked adult male rats were recaptured at least 1400 meters from the bait stations and as long as seven months after exposure to TC.

7. The effectiveness of the sustained baiting method was tested in protecting 100 hectares of ricefields adjacent to marshes bordering the Chico River near San Antonio, Nueva Ecija (the last 100 of 1900 hectares to be harvested in the area, see # 6 above). Baiting followed closely the interagency recommendations for Masagana-99. Monthly records were maintained on the amounts of bait used, numbers of bait stations, and rat activity (by using tracking tiles and records of trap success). Damage appraisal was conducted within two weeks of harvest and compared with adjacent areas where farmers used traditional control methods, and harvest records were obtained from the farmers. Bait consumption increased rapidly during the first nine weeks of baiting, then decreased rapidly as more rats contacted and were affected by the bait. Rat activity (as measured by both tracking tiles and trap success) dropped dramatically by the second month of baiting and remained low thereafter. Despite intense rat pressure, cost for control was estimated at less than ₱50 per hectare. Farmers in the treated area averaged 6.0% tillers cut while damage in adjacent fields was 70% or more. Although most of the harvest in the treated field was lost to flooding (caused by Typhoon Didang), yields in fields that were harvested averaged 75 cavans per hectare. In contrast, most farmers in adjacent fields reported complete loss of their crops to rats. We concluded that the sustained baiting program effectively protected the one hundred hectare baiting site (which was the last to be harvested, was adjacent to marshland, and represented one of the most severe situations for protection from damage that is encountered in Philippine ricefields) from serious rat damage, at low cost, and with potentially high economic return.

8. To compare the operational characteristics of a non-lethal electric barrier with those of a lethal one, we conducted a small scale field trial with the cooperation of the International Rice Research Institute (IRRI). Six plots, about one-quarter hectare each, were provided for the study. Plots were paired, one lethal barrier and one non-lethal barrier, in three different areas along the periphery of IRRI experimental fields. Temperature, relative humidity and voltage of the non-lethal barriers were recorded daily from 10-13 weeks after transplant (WAT). In addition, tracking tiles were used to measure rat activity inside and outside each of the fences at the vegetative, booting and maturing stages of development, and damage appraisal was conducted for each plot within two weeks of harvest. Voltage of the non-lethal fence did not correlate well with either temperature or relative humidity. Batteries used to operate the lethal fences were recharged daily; those used to operate the non-lethal fences were recharged up to two times during the two-month period of study. Rat activity increased during the growing season, and was significantly greater outside than inside the barriers, indicating that both fences afforded some degree of protection. Rat activity was greater, however, within plots surrounded by lethal barriers than non-lethal barriers, average 5% vs 1% respectively. Damage in plots surrounded by lethal barriers averaged 2.05%; those surrounded by non-lethal barriers averaged 0.23% tillers cut. We concluded that the non-lethal barriers provided comparable or better protection from rat damage than the lethal barriers without the need for a night crew to remove electrocuted animals and without the need for daily battery recharges.

9. To determine the potential hazard of warfarin to local domestic chickens (Gallus gallus), we conducted two successive tests in which 33 day old broiler chicks were exposed (by gavage) in groups of four to the following concentrations of warfarin: for the first test, 0, 25, 125, and 470 mg per kg body weight; for the second test, 0, 625, 705, and 1057 mg per kg body weight. Animals were observed for fourteen days after gavage. Four of the fowl died during the period of observation (one each at 0, 470, 625, and 705 mg per kg body weight), but only two of these had symptoms of anticoagulant poisoning (one at 470 and one at 705 mg per kg body weight). We concluded that use of warfarin as recommended for reduction of rat damage to rice in the Philippines represents an extremely low hazard to domestic chickens by accidental poisoning, providing the farmer follows the recommended baiting program and does not allow his fowl to eat treated bait as a substitute food source for extended periods of time.

10. A baiting program using anticoagulants was evaluated on six, two-hectare corn plots in an area where R. r. mindanensis, R. argentiventer, R. exulans, and S. murinus were found. Three plots were randomly selected for treatment, three as reference plots. For treatment, we employed the continuous use of chronic toxicants at three baiting points per hectare, starting on the sixth week after planting. Stations were refilled two-three times weekly and adjusted to maintain a slight excess over consumption. In reference plots, rat activity remained about the same as the cropping season progressed, while it decreased rapidly in the treated plots. There was about an 84% reduction of damage in the treated plots. Cost of control was estimated at about ₱30 per hectare and yields in treated plots were about 4.4 cavans per hectare greater than in reference plots. Cost/benefit was estimated at about 1/7. We concluded that sustained baiting with anticoagulants effectively reduced damge in the treated corn plots, with apparently fair economic return.

11. Distributional maps of rat damage in cornfields were used as models on which to simulate potential sampling methods. Maps of damage were obtained for two cornfields, one 0.15 hectare with 15.04% damaged hills and one 0.35 hectare with 4.85% damaged hills. Three sampling methods (random, systematic, and random-clumped) were tested five times each on the maps. The systematic method had the lowest variability but the random method appeared most accurate. We concluded that additional studies are required to determine which methods will provide the best results with the lest effort in the field, but that the use of distributional maps as models for testing sampling methods provided a relatively quick and sensitive means of comparing the reliability of the methods.

12. The relationship between kernel weight and area occuppied on ears of corn was investigated to determine if it might serve as the basis for a simple, reliable means of predicting corn loss to rat damage. Sample ears (40) of mature, field-dried corn of various sizes were randomly picked at harvest from ears having rat damage in a seven hectare cornfield. Carbon paper and tracing paper were used to obtain impressions of the areas damaged and not-damaged on each ear and profiles of these areas was transferred to graph paper. Greatest length (with kernels) of the ear, length and width of damage, and weight of undamaged kernels were obtained for each ear. Area of damaged and undamaged portions of each ear were obtained by using a polar compensating planimeter. The sample included ears with about a threefold variation in size and a wide range of damage. The area of undamaged corn and its weight was highly correlated ($r = 0.96$, $P \ll 0.001$) with a single linear equation. We concluded that this relationship may serve as a means of predicting corn loss, and that additional studies are warranted.

13. In a trial on the use of methyl carbamate and fenthion as bird repellents, six small plots were located within a two hectare ricefield at three weeks before harvest: two were sprayed with methyl carbamate (4.7 kg active ingredient per hectare); two were sprayed with fenthion (0.9 gallon containing 50% emulsifiable concentrate per hectare); and, two were left untreated. Plots treated with methyl carbamate and fenthion averaged 6.5% and 7.0% damaged hills respectively, while the two untreated plots averaged 22% damaged hills. We concluded that both compounds hold promise as repellents, but that larger, more detailed studies are required to verify results.

14. Observations of bird damage were made on small plots of rice at hard dough stage. Damage was significantly greater along the shorter edges (widths) of the plots than along the other edges and inside the plots, but additional studies are required to see if this preference occurs in larger fields. In a study site in Mindoro Oriental, Lonchura malacca nested in calamansi (citrus) trees from February through May and from July through October and young were observed in March and April and August through October (trees were pruned in September and no nests were observed). This indicated a bimodal breeding season for L. malacca at the study site. In an acute oral toxicity trial, methamidophos was more toxic than carbofuran to L. punctulata, but considerably less toxic than carbofuran to L. leucogaster, L. malacca, and Passer montanus.

15. Over three hundred visitors from many countries were briefed on Center activities, given technical assistance in the form of literature on rodent control, or advice on program planning. Over 200 requests for technical information on rodent control were filled with Center publications, and others with copies of appropriate materials from bibliographic files.

16. Center staff members participated in the training of over 3000 government extension personnel and key farmers in vertebrate pest management methodology, and others in research methodology for vertebrate pest management. Trainees represented a variety of governmental agencies, including the Bureau of Plant Industry, the Bureau of Agricultural Extension, Philippine National Bank, Agricultural Credit Administration, Agricultural Credit and Cooperative Institute, Farm Systems and Development Corporation, National Food and Agricultural Council, and Philippine Sugar Institute.

17. One research trainee from Nigeria spent almost three months participating in a variety of on-going research and methods evaluation studies and worked independently on a project proposal related to vertebrate pest problems in Nigeria.

18. Staff members taught or helped teach courses in Vertebrate Pests, Experimental Design, and Wildlife Management at the University of the Philippines at Los Banos, with several classes and laboratories held at the Center.

19. The Government of the Philippines encouraged the use of sustained baiting with anticoagulants in ricefields through its national rice production program, Masagana-99, and its national rat control programs for non-Masagana-99 areas. Implementation of the rat control aspects of these programs was initiated through intensive training of extension officers, and, education of farmers in current methods involving use of acute toxicants and mechanical control to reduce population levels, then use of the sustained baiting program for long-term damage reduction. Preliminary surveys in target areas indicated that farmers who followed these recommendations were able to successfully protect their crops from serious rat damage.

20. Director Sanchez was nominated as the invitational speaker for the 1976 Annual Meeting of the Entomological Society of America, held in Honolulu, Hawaii, in November-December. In his keynote address, Dr. Sanchez summarized the current status of rice pest management in the Philippines. He later attended a conference, co-sponsored by the East-West Food Institute and the University of Hawaii, on the Impact of Pesticide Laws. Earlier in the year he had attended a conference in Hawaii on the Consolidation of Crop Protection Courses and presented a paper on the training needed by the pest management specialist.

21. In its third year of operation, the library now contains 716 books and pamphlets, 66 center publications, 872 reprints, 57 periodicals with a total of 1019 volumes, 94 maps and over 700 photographs. Newly established functions of the library include periodic literature searches, development of bibliographies, and distribution of content lists for journals that publish articles on vertebrate biology and control.

22. The following reports were published or presented in proceedings of meetings by Center staff members:

Benigno, E. A., R. F. Reidinger, J. L. Libay, and F. F. Sanchez. 1976. Sustained baiting with anticoagulant rodenticides in cornfields and assessment of rat damage. Proc. 7th Nat. Pest Cont. Council Conf. 7: 146.

Ferrer, L. S. 1976. Growth of Rattus rattus mindanensis Mearns. The Philippine Agriculturist 59 (1-2): 37-42.

Hoque, M. M., R. F. Reidinger, J. L. Libay. 1976. Crown-baiting in coconut trees using anticoagulant rodenticide to reduce rat damage. Proc. 7th Nat. Pest Cont. Council Conf. 7: 148.

Libay, J. L. and M. W. Fall. 1976. Observations on an exceptionally dense population of wild rats in marshland. Kalikasan (Philippine J. Biol.) 5: 207-212.

Reidinger, R. F. 1976. Organochlorine residues in adults of six southwestern bat species. J. Wildl. Manage. 40(4): 677-680.

Sanchez, F. F. 1976. Knowledge that the pest management specialist will need. Presented at the Workshop on the Consolidation of Crop Protection Courses, sponsored by the East-West Food Institute and the College of Tropical Agriculture of the University of Hawaii, held in Honolulu from January 5-9.

Sanchez, F. F. 1976. The current status of the rice pest management in the Philippines. Keynote address at the 1976 annual meeting of the Entomological Society of America, held in Honolulu, Hawaii from Nov. 29-Dec. 3, 1976.

Sumangil, J. P. 1976. The national rat control program. Proc. 7th Nat. Pest Cont. Council Conf.

West, R. R., M. W. Fall, and E. A. Benigno. 1976. Comparison of snap traps and tracking tiles for obtaining population indices of *Rattus rattus mindanensis* in the Philippines. Philipp. Agric. 59(9,10): 379-386.

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Sanchez, F. F., et al. 1972. Rodent Research Center 1972 Annual Progress Report. 50 pp.

Sanchez, F. F., et al. 1973. Rodent Research Center 1973 Annual Progress Report. 94 pp.

Sanchez, F. F., et al. 1974. Rodent Research Center 1974 Annual Progress Report. 102 pp.

Sanchez, F. F., et al. 1975. Rodent Research Center 1975 Annual Progress Report. 89 pp.

Stone, C. P., D. F. Mott, J. F. Besser and J. W. De Grazio. 1972. Bird damage to corn in the United States in 1970. The Wilson Bulletin 84(1): 101-105.

Stone, C. P., D. F. Mott, J. F. Besser and J. W. De Grazio. 1973. Bird damage to ripening corn in the United States, 1971. Wildlife Leaflet 505. U.S. Dept. of Interior. 7 pp.

Williams, J. M. 1974a. Rat damage to coconuts in Fiji. Part 1: assessment of damage. PANS 20: 379-391.

Williams, J. M. 1974b. The effect of artificial rat damage on coconut yields in Fiji. PANS 20: 275-282.

Woronecki, P. O., et al. 1973. Cali, Colombia Field Station 1973 Annual Progress Report. 42 pp.