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Economic losses by rats on experimental rice farms in the Philippines

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ABSTRACT. Fifty-one scientists at the International Rice Research Institute took part in a survey to determine the extent of rat damage on experimental rice fields in 1980 and the resultant data loss. Their responses suggested that rat damage occurred in 86·0% of 171 field experiments, causing complete loss of data in 6·4% and partial loss in 59·1%. Survey results indicated that rat damage was unaffected by season or among plots protected by a non-electrified fence, electrified fence, or no fence. The incidence of complete loss of research data was highest in experimental plots protected by an electrified fence. Data losses were estimated as equivalent to monetary losses of about US$370 000 for 1 year.

Introduction

Rodent damage to agricultural crops at tropical research stations is a chronic, sometimes acute, pest problem that results in loss of research time and money. Research stations in India (Kulshreshtha, 1968; Srinivasalu, Velayutham and Subramaniam, 1971; Peswani *et al.*, 1975), Thailand (Anonymous, 1967), Burma (E. H. Glass, personal communication), and Indonesia (J. A. Litsinger, personal communication) have significant rodent problems. Several different rodent species and a variety of crops are involved. Research stations located near farmers' fields or other habitats harbouring rats are subjected to continuous immigration requiring persistent control efforts. Research efforts in the Philippines by Denver Wildlife Research Center personnel led to recommendations for rat control in individual farmers' rice fields that accounted for this immigration or 'sink' effect (West, Fall and Libay, 1975; Fall, 1977).

The International Rice Research Institute (IRRI) at Los Baños, Philippines, has about 252 ha of experimental farms of which 230 ha are rice or rice-based crops (Chandler, 1982) with rat damage resulting in unquantified losses of research data every year. *Rattus rattus mindanensis* (Mearns) is the most prevalent rodent species (98·4% present) followed by *R. exulans* (1·6%) (Uhler, 1967).

The experimental farm is composed of four geographic areas separated from each other by a river, stream or distance (Figure 1). Areas 1 (25 ha) and 3 (78 ha) are contiguous with rice fields of local farmers who may or may not practise good rodent control. Area 1 contains some non-IRRI plots which lie fallow and weedy much longer than IRRI plots and which do not receive regular continuous rodent control. The Institute's offices, laboratories and service buildings are largely in Area 1. Area 2 (42 ha) shares only a small border with local farmers' rice paddies outside the experimental farm. Area 4 (107 ha), unlike Areas 1–3, consists mostly of upland non-irrigated research plots, with some irrigated rice and a variety of upland crops.

Various control techniques have been used in the fields, including physical barriers (Ramos, 1967, 1970) and anticoagulant rodenticide baiting. Before electrified fences were used, periodic baiting with acute rodenticides (zinc phosphide or sodium monofluoroacetate) for 1 or 2 days was followed by chronic anticoagulant rodenticides and burrow fumigation with cyanide. To a limited extent, physical examination methods have also been used: digging burrows, clubbing during harvest and subjecting burrows to a locally made flame thrower. Cyanide fumigation of rat burrows was discontinued in 1979 when its use was restricted by the Philippine Fertilizer and Pesticide Authority. Most of the experimental plots are enclosed by fences, some of which are electrified at night if there have been rat problems in the immediate area, if the type of experiment is particularly vulnerable, or if it has been requested by the researcher. The department head or researcher in co-operation with Farm Operations Department, which conducts rodent control, decides which methods will be used. From 1979 to 1983, about 40000 dead rats have been recovered annually, and an unknown number killed by rodenticide baiting. Even though major efforts have been undertaken, rats continue to cause yield losses, which lead to inconclusive and unreliable research results.

In view of this continuing problem, the observations of IRRI research personnel were solicited (1) to determine the occurrence of rat damage in experimental rice fields; (2) to estimate the extent of lost research data attributable to this observed rat damage; (3) to determine how respondents rated importance of the rat problem affecting their research. Survey data were then analysed to determine whether data loss was influenced by plot location, season, or rat-control methods.

Methods

A survey was conducted among IRRI personnel conducting rice field trials on the IRRI farm from January to December 1980 by soliciting information on the occurrence of rat damage and the resultant loss of experimental data. A survey form was distributed to IRRI department heads with a request memo from the Entomology Department. The number of forms distributed was based on the size of each department as listed in the most up-to-date annual report (IRRI, 1978). Plot size and location, time of the experiment, rat-control methods used, occurrence of rat damage, and an estimate of data loss as either complete, partial or none, were noted for each experiment conducted. The researchers were also asked to rate the rat problem as severe, moderate, or negligible and to give their opinion on whether rat damage and subsequent loss of data had become worse over the previous 3 years, following the discontinuation of cyanide fumigation of rodent burrows.

Survey data from individual experimental plots were taken from four areas to assess differences between locations (Figure 1). Experimental plots harvested from August through January were labelled 'wet season', and those harvested from February through July were labelled 'dry season', to identify any seasonal effects. Different physical barrier systems, namely the non-electrified fence, electrified fence and no fence, were compared. The data were analysed by chi-square tests to detect differences in rat damage and data loss between different locations, seasons and rat-control methods.

Total rice land area (230 ha) on the farm averaged about 2·0 experiments/plot/year, resulting in about 460 ha of effective experimental rice hectarage. Field research costs including rice cultivation, pest control and experimental sampling and observation by research staff were then used to estimate cost/ha/year for conducting rice research. Costs of laboratory research, administrative support staff and senior staff salaries were not included, although a portion of each could have been related to field research and, thus, affected by the data lost because of rat damage.

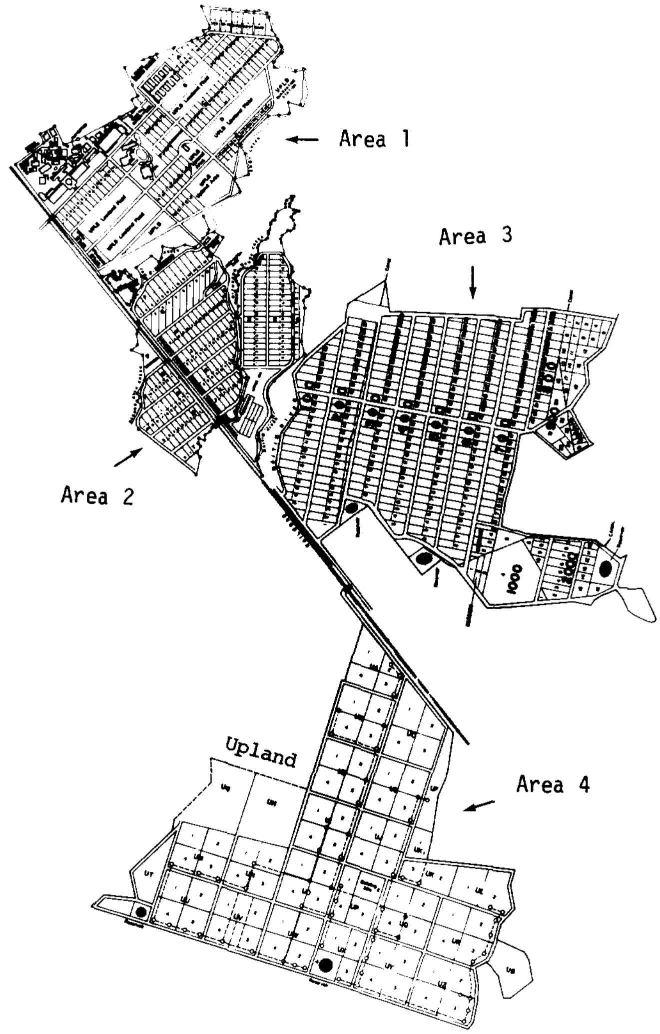

FIGURE 1. The International Rice Research Institute consolidated experimental farm, 1980. Total hectarage 252 ha (Area 1, 25 ha; Area 2, 42 ha; Area 3, 78 ha; and Area 4, 107 ha), of which 230 ha are rice or rice-based. (Courtesy of Farm Operations Department, IRRI.)

Economic losses in 1980 resulting from rat-damaged rice research plots were estimated by extrapolating the results from the survey sample to the rice land of the entire IRRI farm. The percentage of experiments in which 100% data were lost due to rats (T) was used to estimate the experimental hectarage in which all data were lost. The same procedure was used to estimate hectarage with no data lost due to rat damage. For partial data lost (P), which ranged between 1% and 99%, we conservatively assigned a value of 10% to represent the mean percentage estimate of research data loss due to rats. The estimate of data loss in US$ (L) from rat damage for the entire experimental rice area (460 effective annual ha) was then determined by

$$L = [T \times 460 \times RC] + [P \times 460 \times RC \times 0 \cdot 10]$$

where RC = field research costs/ha/year (US$).

Results

Fifty-one researchers (about 36% of those potentially involved in conducting field experiments with rice) from seven departments responded to the survey. They conducted 171 experiments which were uniformly distributed among the four major areas of the experimental farm land (Table 1). More experiments were conducted during the wet season (112) than during the dry season (35) (Table 2), and most of the plots (163) were protected by a fence (Table 3).

Plot size in each of the four areas was similar ($\bar{x}$ = 6386 m^2). Exceptions were a higher number and percentage of small plots (≤3000 m^2) in Area 2 and a higher number and percentage of large plots (>10000 m^2) in Area 3.

Respondents reported rat damage in 86·0% of the 171 experimental plots (Table 1). All research data were lost in 6·4% of these experiments whereas 34·5% had no loss at all. The lowest occurrence of damage was in Area 2. There was no significant difference in the occurrence of rat damage and research data lost between the wet and dry seasons (Table 2).

The survey also showed little difference in the occurrence of rat damage between plots with fences, whether electrified or not, and no fences (Table 3). In about 66% of all fence-protected plots, some research data were lost versus 75% in unprotected plots. Complete data loss occurred more often in protected plots.

Seven different methods of rodent control were identified from the survey forms (Table 4). On only one of the 171 plots were no control methods used. More than 95% of the plots used a fence, either non-electrified (53·8%) or electrified (41·5%). Area 1 had the highest percentage of electrified fences (82·1%)

TABLE 1. Occurrence of rat damage and the percentage of research data lost in 171 experiments conducted on the IRRI experimental farm during 1980

Area†	No. of experiments	Occurrence of rat damage (No.)	Occurrence of rat damage (%)	Research data lost: Complete (No.)	Complete (%)	Partial (No.)	Partial (%)	None (No.)	None (%)
1	39	36	92·3	8	20·5	21	53·8	10	25·6
2	44	33	75·0	1	2·3	18	40·9	25	56·8
3	50	47	94·0	1	2·0	38	76·0	11	22·0
4	38	31	81·6	1	2·6	24	63·2	13	34·2
Total	171	147		11		101		59	
Mean			86·0		6·4		59·1		34·5
Chi-square‡			$2{\cdot}8^{NS}$				$69{\cdot}2^{**}$		

† Area 1 = Blocks A–E; Area 2 = Blocks F–T; Area 3 = plots 101–2016; Area 4 = upland plots.
‡ NS = not significant; ** = highly significant ($P<0{\cdot}01$).

TABLE 2. Seasonal effect on the occurrence of rat damage and research data loss based on 147† experiments conducted on the IRRI experimental farm during 1980

Season†	No. of experiments	Occurrence of rat damage (No.)	Occurrence of rat damage (%)	Research data lost: Complete (No.)	Complete (%)	Partial (No.)	Partial (%)	None (No.)	None (%)
Wet	112	92	82·1	2	1·8	68	60·7	42	37·5
Dry	35	31	88·6	3	8·6	21	60·0	11	31·4
Total	147	123		5		89		53	
Mean			83·7		3·4		60·5		36·1
Chi-square‡			$0{\cdot}3^{NS}$				$5{\cdot}0^{NS}$		

† Twenty-four experiments were not included because of non-specific harvest dates listed on survey form.
‡ NS = not significant.

TABLE 3. Effects of control methods on the occurrence of rat damage and data lost from 171 experiments conducted on the IRRI experimental farm during 1980

Control methods	No. of experiments sampled	Occurrence of rat damage (%)	Research data lost: Complete (No.)	Complete (%)	Partial (No.)	Partial (%)	None (No.)	None (%)
Fence	92	84·0	2	2	58	63	32	35
Electrified fence	71	88·7	9	13	38	54	24	34
No fence	8	87·5	0	0	6	75	2	25
Total	171		11		102		58	
Chi-square†		$0{\cdot}2^{NS}$			$25{\cdot}2^{**}$			

† NS = not significant; ** = highly significant ($P<0{\cdot}01$).

TABLE 4. Number and percentage of selected plots using different rodent control methods within each of four locations (Areas) on the IRRI experimental farm, 1980

	Area									
	1		2		3		4		Total	
Control method	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Fence		15		36		74		87	92	54
Electrified fence		82		59		20		8	71	42
Baiting		82		86		86		74	141	83
Digging burrows		36		50		76		42	90	53
Catching		3		14		0		0	7	4
Trapping		0		0		0		5	2	1
'Flame thrower'		0		0		2		0	1	0
None		0		0		0		3	1	0
Total methods	85		108		129		83		405	
Total plots	39		44		50		38		171	
Mean no. methods/plot	2·2		2·5		2·6		2·2		2·4	

while Area 4 had the smallest (7·9%). Most plots (83%) were baited with a rodenticide and in more than half (53%), rat burrows were dug out.

Efforts to control rats, or the number of methods used, were greatest in Area 3, where a mean of 2·6 different rat-control methods/plot were used, followed by Area 2 (2·5 methods/plot). Corresponding figures for Areas 1 and 4 were 2·2 methods/plot.

About 29% of the 51 researchers surveyed thought that the rat 'problem' in their plots was severe; about 26% considered it to be negligible; 45% were between these extremes. Nine of 16 people in the Plant Breeding Department rated the rat problem as severe—a much higher proportion than in any other department. The majority of the respondents (67%) felt that rats had become a greater problem over the previous 3 years.

Discussion

Crop losses by rodents in farmers' rice fields are difficult to estimate in economic terms (Benigno, 1980; Greaves, 1982). Vertebrate pest damage presents even greater difficulties in experimental plots where research data and scientific labour are at issue. This lack of quantified economic loss data may be a major reason why control of rat damage has been given considerably less attention than other plant-pest problems (Fall, 1977). A Filipino farmer may invest as much as ₱2000 (US$140) to grow 1 ha of rice during a 4-month crop cycle. A research institute, such as IRRI, may invest more than $6522/ha to obtain additional knowledge that may subsequently be useful to individual farmers. Both farmer and researcher therefore stand to lose a significant amount of time and money if substantial rodent damage occurs.

Data loss from rat damage appeared to be greater in some field trials at IRRI than others. For example, experiments located in Area 1 had a significantly higher percentage of complete research data lost, whereas more than one-half of the experiments in Area 2 had no research data lost. Experimental plots located in Area 3 had the greatest occurrence of rat damage (not significant) and a higher percentage of research data lost (both complete and partial). Areas 1 and 3 (unlike Areas 2 and 4) shared a considerable border with neighbouring local rice fields which, when harvested, increased the risk associated with immigrant rats moving to as yet unharvested experimental fields within IRRI.

Factors other than location which may have contributed to greater research data loss include seasonal effects (wet and dry), intensity (number and type) of rodent control methods used and plot size (small vs. large): none of these factors, however, were statistically significant (Tables 2, 3, 4). Significant differences in research data loss were associated only with location (Table 1). While a significantly greater number of experiments using an electrified fence resulted in complete research data loss, most were located in Area 1, which was particularly susceptible to rat damage.

There was no obvious explanation why Area 2 had the lowest incidence of damage and the least occurrence of data loss, although this Area contained more small plots (91% of plots $\leqslant 3000\,m^2$) than the other areas (38–69%): rats may have had more difficulty in establishing themselves inside smaller plots. A similar percentage (about 95%) of plots in the survey were fenced in all areas (*see* Table 4), but metres of fence per hectare were 146, 90, 82, and 44 in Areas 1–4, respectively. More fencing per unit area may have been a factor limiting immigration of rats to Area 2, but probably not Area 1, which had the greatest amount of fencing per unit area. Detailed studies on marked rats (both immigrant and resident) are needed to determine the effects of fencing on limiting rat movement and subsequent damage in research plots.

The mean number of reported rat-control methods used per plot provided a measure of the intensity of rodent control. These means were higher in Areas 2 and 3. The combination of smaller plot sizes, more fencing per unit area, and greater rodent control efforts may have contributed to the lower levels of rodent damage and data loss reported by IRRI researchers in Area 2.

The fact that plots protected by an electrified fence had a higher incidence of rat damage and percentage of complete research data loss could be misleading, as plots with electrified fences were usually located in areas with a history of serious rodent problems. Electrified fences should, in general, perform at least as well as non-electrified fences, assuming fence configuration and soil seal were similar. Exclosure fences designed to keep rats out of plots can easily become enclosures if rats somehow enter fenced areas. Ahmed (1981) showed that a properly maintained electrified fence resulted in the lowest rodent activity and damage to rice when compared with baiting or with a non-lethal, electrified net barrier.

Two out of every three surveyed rice experiments conducted at IRRI during 1980 resulted in at least some lost data due to rat damage. The economic significance of these losses was determined by estimating some direct monetary losses.

About \$369 315 of rice research costs in 1980 were lost because of rodents, while \$2630685 of the research costs were not thus affected (Table 5). Monetary losses attributable to rats were therefore more than 12% of total estimated field research costs. These losses represented investments in land preparation, planting, pest (bird, insect, and rodent) control, and staff time involved in field experimentation; however, it does not include administrative costs, including senior staff salaries, which would increase our estimate of \$6522 in rice field research costs/ha/year. To our knowledge, no other single pest or disease consistently results in annual research data loss of this estimated magnitude.

Vertebrate pest problems, usually rodents or birds, or both, occur on most research farms like IRRI. Most such farms have varying degrees of operational control programmes to protect research plots from rat damage. When rat damage is kept within acceptable limits (dependent on the type of experiment), then scientists can account for such yield losses when reporting their research results (Reidinger, Libay and Ocampo, 1978). It is highly probable that yield data have been regularly reported that were, unknown to researchers, affected by rodent damage.

TABLE 5. Estimated monetary losses caused by rats in experimental rice plots at the International Rice Research Institute, 1980

Research costs	
Experimental rice land area	230 ha
No. of experiments/plot/year	2
Effective rice land hectarage	460 ha
1980 field research costs*	\$3000000
Field research costs/ha	\$6522
Research losses due to rodents	
6·4% (complete data loss) × 460 ha × \$6522	\$192008
59·1% (partial data loss) × 460 ha × \$6522 × 10%**	\$177307
Total loss due to rats	\$369315

* Includes: land preparation (\$51238); planting inputs—planting (\$13890), weeding (\$37981), fertilizers (\$28019), insecticides (\$82058), herbicides (\$21767); pest control—birds (\$110272) and rodents (\$64403); junior research staff salaries (\$552000); labourers (\$1104000); laboratory staff salaries (\$179400); supplies and equipment (\$524972); transportation (\$230000).
Excludes: senior staff salaries and administrative support staff
(Source: IRRI Farm Budget and Departmental Costs for 1980).

** A conservative estimate of the percentage data loss incurred by experiments that identified partial data loss due to rat damage.

Research data losses can be disastrous for visiting scientists and students with only a limited time schedule to complete their fieldwork. For example, a student at the Bangladesh Rice Research Institute, collecting data from a deepwater rice experiment, lost all meaningful research results after more than 6 months of fieldwork, because of rat (*Bandicota* spp.) damage. If recommended baiting procedures had been used around the experimental site, rodent damage would have been reduced, thus allowing most of the experimental data to be collected. In a weed control experiment at IRRI (Area 4), rat damage threatened the complete loss of thesis research data. The graduate student modified his experimental design so that a major objective became the evaluation of the relationship between weeds and rat damage to rice (Drost and Moody, 1982).

Our results reflected a general attitude among IRRI researchers that rodents were a significant factor limiting their research and should be considered a serious problem. About 75% of these researchers rated the rodent problem as more than just negligible, and 67% said that it was worse than it had been 3 years earlier. However, there is no direct evidence that rat damage actually increased at IRRI, because rat damage was not routinely assessed during that period. Indirect evidence, such as rodent kill and recovery data, is not supportive. The only major change in operational rodent control on the IRRI farm that has occurred since 1979 has been the elimination of burrow fumigation with cyanide; however, unpublished data collected in IRRI rice fields has indicated that burrow fumigation does not reduce rat activity, or reduce rat damage to maturing rice.

The rodent pest problems identified in this study are not confined to IRRI and are common in tropical experiment stations world wide where rice and other crops are grown intensively. This study indicates that losses from rodent damage in time, money and new knowledge, are substantial and that increased research into rodent damage is needed. This should lead, not only to lower research costs on experimental rice farms, but also to the development of technology effective in reducing yield losses due to rats in farmers' fields.

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