PN-AAR-153
ISN: 36645
256

PHIL. AGR. 63:239-250
JULY-SEPT. 1980

ISSN 0031-7454

RAT DAMAGE DISTRIBUTION IN RICE AND CORN FIELDS

EDWIN A. BENIGNO

A portion of the Ph.D. dissertation of the author.

Researcher, National Crop Protection Center, University of the Philippines at Los Baños, College, Laguna.

CESC No. 3453. Received for publication 26 March 1980.

Rat damage was reportedly concentrated in the middle of the rice fields during periods of heavy rat infestation, and along the dikes during periods of low infestation. In most cases, damage was assumed to be randomly or uniformly distributed in the field.

Distribution of rat-damaged rice and corn plants was further investigated through simulated field sampling on the computer. Data came from 5 lowland transplanted ricefields and 6 cornfields where every plant was sampled.

Results indicate that sample plot size influences distribution. In general, counts of damaged plants in small plots fit the Poisson distribution indicating randomness. For most sample plot sizes, damage in ricefields was fairly randomly distributed. Damage in cornfields appeared to cluster especially along the edges adjacent to uncultivated fields.

Distributional maps were also derived from computer plots of the damaged plants. The maps showed that corn fields had more damage along the edges than in the middle while rice fields had random or uniform damage distribution. These findings suggest the suitability of stratified sampling for rat damage assessment in corn and simple random sampling for rat damage assessment in rice.

INTRODUCTION

Efficient sampling and analysis of rat damage depend on a basic understanding of spatial damage distribution in an area, temporal distribution with respect to season and stage of crop development, and damage distribution within the plant (Linehan, 1967). Spatial distribution of rat-damaged plants in the field may be random, aggregated or regular depending on factors such as rat species involved and population pressure, type and age of crop, and the adjacent habitat. During heavy infestation of *Rattus rattus mindanensis*, damage was concentrated in the middle of ricefields (Mueller, 1970) while during periods of low infestation, damage occurred along field edges. With *Bandicota bengalensis*, damage appeared patchy around burrows or nests (Fall, 1975).

Rodents infesting sugarcane were reported damaging canes near field edges especially those near wastelands. Later damage extended throughout

the field (Hood et al., 1971; Williams, 1953). Damage by *Holochilus sciureus* was concentrated at the field periphery and rarely occurred inside the field (Bates, 1963). Cotton rats *(Sigmodon hispidus littoralis)* in Florida restricted feeding activities to within 200 feet of sugarcane field boundaries (Doty, 1959). Similarly, rat damage in cornfields appeared to be influenced by proximity to uncultivated adjacent areas (Sanchez et al., 1976).

Distribution of damaged plants can also be described quantitatively through some theoretical distributions. Randomness is indicated by a good fit of observed data to the normal distribution when counts are "high", or to the Poisson distribution when counts are "low" (Waters et al., 1959). Aggregation is indicated by a good fit to the negative binomial.

Distribution is random if the presence of a damaged plant in a sampling unit has no effect on the chances of another damaged plant in the same unit.

Whether the presence of a damaged plant increases or decreases the chances of its neighbors being damaged depends largely on the rats' feeding behavior. Little is known about this although West et al. (1975) reported that tiller-cutting rates varied with age of the rice plants.

This study was conducted to examine spatial distributions of infield damage under different field conditions and to describe these quantitatively by means of the Poisson and negative binomial distributions.

MATERIALS AND METHODS

Five rice-transplanted lowlands and 6 cornfields were thoroughly surveyed for rat damage. The fields were approximately rectangular in shape with plants arranged in rows. Complete enumeration of damaged and undamaged hills was made in one ricefield and only damaged hills in other fields. Similarly, each plant in the cornfields was examined for damaged corn ears. Missing plants and unplanted patches within the fields were noted.

For purposes of mapping and simulated sampling, each plant or hill was identified by its row number and position within the row (column). Additional data on planted variety, age of crop, farm practices and description of surrounding fields were gathered. Table 1 summarizes field descriptions.

Data were analyzed using Statistical Analysis System (SAS) Programs (Barr et al., 1976) at the Agricultural Resource Center, University of the Philippines at Los Baños. Additional programs on field plot techniques and distribution fitting (Poisson and negative binomial) were made. Distributional maps were redrawn from computer plots of damaged plants.

The following units (number of rows x number of plants) were examined: 1 x 1, 1 x 5, 1 x 10, 2 x 2, 2 x 5, 2 x 10, 2 x 4, 2 x 6, 3 x 5, 3 x 10, 5 x 5, 5 x 10, and 6 x 6. Frequency counts of damaged plants and tillers (for rice only) of different plot sizes were tested for goodness of fit to either

2

Table 1. Description of farms surveyed for rat damage.

Farm No.	Crop	Maximum No. of Rows	Maximum No. of Hills/Rows	Distance of Planting (M)	Field size (Ha.)	Crop Age (Weeks)
1	Corn	114	119	0.50 x 0.50	0.32	8
2	Corn	61	102	0.33 x 0.33	0.25	8
3	Rice	255	50	0.25 x 0.25	0.25	10
4	Rice	50	100	0.17 x 0.17	0.25	14
5	Rice	100	90	0.20 x 0.20	0.75	16[a]
6	Rice	50	110	0.17 x 0.17	0.75	16[a]
7	Rice	77	125	0.17 x 0.17	0.13	16[a]
8	Corn	130	120	0.80 x 0.75	0.94	15
9	Corn	130	125	0.80 x 0.75	0.97	15
10	Corn	156	110	0.80 x 0.75	1.30	15
11	Corn	165	110	0.80 x 0.75	0.98	15

[a]Farm harvested late; rice plants showed retillering.

Poisson or negative binomial distributions using χ^2 — test. Distributions of damaged tillers within hills were also analyzed.

Goodness of fit of the theoretical distribution to the observed data was tested by use of the following equation:

$$\chi^2 = \frac{\Sigma (f_i - E_i)^2}{E_i}, \quad \text{d.f.: } n - 1 \text{ for Poisson}, \quad n - 3 \text{ for negative binomial}$$

where f_i is the observed frequency in the ith class; $E_i = P(x)N$, the expected frequency under the theoretical distribution under consideration; $P(x)$ the probability that the variate takes the value x, $P(x) = \text{Prob}[X = x]$.

For the Poisson, the following equation was used:

$$P(X) = \frac{e^{-m} m^x}{x!}$$

where m represents population mean (estimated by sample mean) and e is the base of natural logarithms, k was determined following Bliss and Fischer (1953).

For the negative binomial,

$$P(x) = \frac{(k + x - 1)!}{x!\ (k - 1)} \cdot \frac{R^x}{q^k}$$

$$\text{where } R = p/q = \frac{m}{k + m}$$

RESULTS AND DISCUSSION

Damage patterns. — Figures 1a and 1b are examples of distributional

3

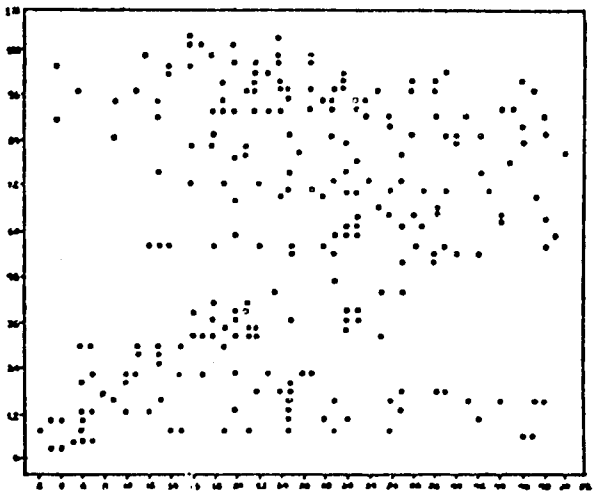

Fig. 1a. Distributional map of rat-damaged rice plants.

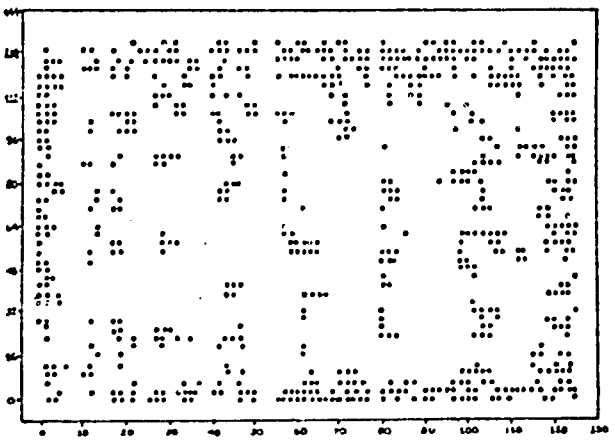

Fig. 1b. Distributional map of the rat-damaged corn plants.

maps of rat-damaged plants as redrawn from computer plots. The dots represent the damaged plants. Some observations however, are "hidden", due to limitations in the computer printer of the scales used. Nevertheless, the maps provide an idea how rat damage might be dispersed in the field whether uniform, random, randomly clumped, uniformly clumped, or aggregate-

4

ly clumped. If there is an evidence of clumping, it is also interesting to know where clumping would likely occur in the field. This can be a useful guide in concentrated animal damage control such as bait placement, and to stratify the field for efficient damage sampling.

Distributional maps indicate that rat damage tends to be more randomly or uniformly distributed in ricefields than in cornfields. Damage in a cornfield appears to be affected by field surroundings especially if the field is uncultivated. Thus, more damage occurs near field edges than in the middle.

In practical application, these findings suggests the suitability of stratified sampling for rat damage assessment in corn and simple random sampling for rice. Peripheral baiting in cornfields is also indicated. This type of bait placement has been found effective in preliminary studies with sustained baiting in corn (Sanchez et al., 1975).

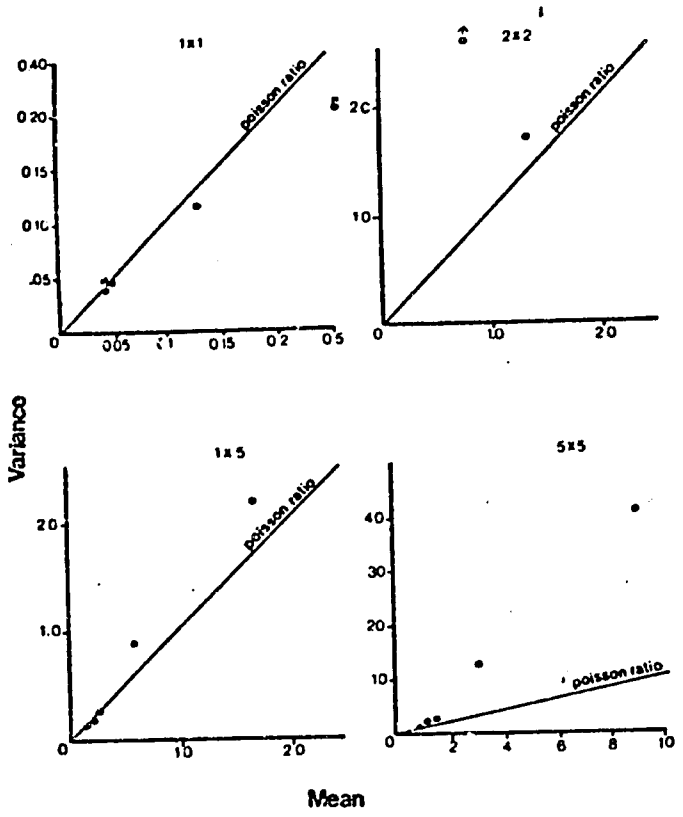

Fig. 2a. Variance-mean relationship of rat damaged rice plants on different sampling units.

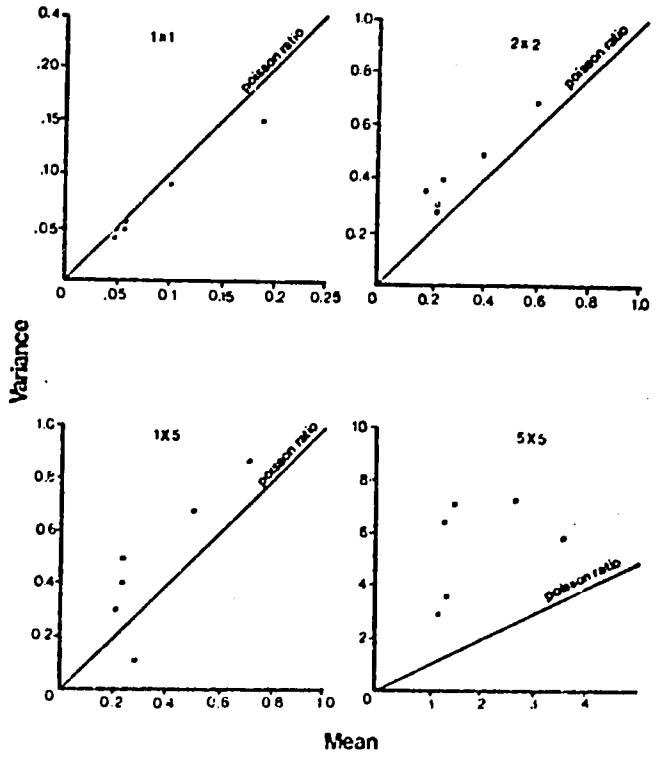

Fig. 2b. Variance-mean relationship of rat damaged corn plants on different sampling units.

Distribution fitting. — Figures 2a and 2b show the variance-mean relationship for different densities (mean number of damaged plant/plot) and plot sizes. The Poisson ratio line represents the points where the mean and variance are equal. Above the line, variance > mean (negative binomial) and below it, variance < mean (binomial).

The figures indicate that sample variances differed from their mean values as plot size and/or density increased. At very low damage densities, variances were about equal to their means; at high densities, the variances were larger except for the 1 x 1 sampling unit. This indicates that individual damaged plants (1 x 1) were randomly distributed at very low densities but as the probability of damage increases, the distribution approached that of the positive binomial wherein variance < mean. The groups of 4 adjacent rice plants (2 x 2) behaved like the individual plants. As plot size increased in both rice and corn fields, variances also increased compared to the mean values, suggesting clumping rather than randomness.

Sample distributions depend largely on the sampling unit. Although the individual plant is the natural sampling unit, sampling is more conveniently done on plots. Yield loss estimation should also be done on per plot rather

6

than per plant basis. Thus, it is interesting to determine how rat-damaged plants in plots of different sizes and shapes would be distributed. Actual fitting of the negative binomial and the Poisson distributions are summarized in Table 2.

The parameters m (Poisson) and k (negative binomial) together with some information on economic injury levels may be used to develop sequential sampling plans such as those developed for fish tapeworm cysts (Oakland, 1950), cotton bollworm (Allen et al., 1972), imported cabbage worm

Table 2. Sampling units showing good fit to the Poisson and negative binomial distributions.

Farm No.	Crop	% Plant Damage	Poisson	M	Negative Binomial	K
1	Corn	4.66	1 x 1	0.05545	1 x 10	0.6200
					2 x 5	0.3653
					3 x 10	0.5612
					5 x 5	0.4628
					5 x 10	0.6790
2	Corn	2.38	1 x 1	0.0222	1 x 5	0.1109
					1 x 10	0.1132
					2 x 5	0.0820
					2 x 10	0.0908
					3 x 10	0.0932
3	Rice	13.25	none	—	2 x 5	0.8402
					2 x 10	0.8383
					3 x 5	0.8720
4	Rice	3.54	1 x 1	0.03649	2 x 5	2.5251
			1 x 10	0.3575	2 x 10	2.5100
			2 x 2	0.1416	3 x 5	1.8590
			3 x 5	0.5364	3 x 10	2.1730
			3 x 10	1.0727	5 x 5	1.7116
					5 x 10	1.3825
5	Rice	35.08	none	—	none	—
6	Rice	4.51	1 x 1	0.0481	2 x 2	3.2600
			1 x 5	0.2400	2 x 5	1.3341
			2 x 2	0.1920	1 x 10	1.7368
					1 x 5	3.5700
7	Rice	2.86	1 x 1	0.0458	2 x 5	2.7810
			2 x 2	0.1819	2 x 6	4.0860
			2 x 4	0.3638	2 x 10	2.4961
			4 x 4	0.7161	3 x 5	3.6460
					3 x 10	2.2234
					4 x 4	3.5300
					4 x 6	2.0410
					5 x 5	2.2632
					6 x 6	1.9744
8	Corn	14.96	none	—	none	—
9	Corn	8.11	1 x 1	0.0810	none	—
10	Corn	4.81	1 x 1	0.0465	5 x 5	0.3662
11	Corn	10.54	none	—	1 x 10	1.3422

(Harcourt, 1966), and forest insects (Waters, 1955).

Table 2 shows which of the different sample plots fitted the Poisson or the negative binomial with positive exponent k. At relatively low densities (2% to 5% plant damage), the distribution of the smaller sampling units (1 x 1, 2 x 2, 4 x 4) fitted the Poisson; that of the bigger plots (5 x 5, 5 x 10), the negative binomial. This tallies with the earlier finding based on the variance-mean graphs of Figures 2a and 2b. At high densities of 35% (farm 5) and 15% (farm 8), none fitted either the Poisson or negative binomial; at 13% (farm 3) and 10% (farm 11), only the negative binomial fitted a few plot sizes.

In some fields, there were sampling units which fitted both distributions (Table 3). Although both the Poisson and negative binomial provided "good" fit as measured against a 0.05 size test (X^2), it is obvious that the negative binomial is preferable. It gave a better fit (P= 0.37) than Poisson (P = 0.08).

Table 3. Fit of observations on 3 x 5 plots in farm 4 to the Poisson and negative binomial.

Number of Damaged Plants	Observed Frequency	Expected Frequency	
		Poisson	Negative Binomial
0	206	193.0075	205.9932
1	84	103.5222	85.7472
2	31	27.7626	27.4468
3	7		
	(9)[a]	(5.7075)[a]	(10.8128)[a]
4	1		
5	0		
6 – 15	1		
Total	330	330	330 (K=1.859)
Damaged plant/plot: $\bar{X}$ = 0.5364 S^2 = 0.6811 I = 0.2844		X^2 = 6.83287 p = 0.08	X^2 = 0.7995 p = 0.37

[a]Total frequency of remaining classes with expected frequencies of 5 or less.

The k value of the negative binomial indicates degree of aggregation. Small values indicate aggregation or clumping; large values indicate randomness. Table 2 shows small k values (<1) in fields where the fit to the Poisson was generally poor. The k values varied from field to field but did not vary much with different plot sizes within the same field. In general, ricefields had larger k values compared with corn fields.

Damaged rice plants tend to be randomly distributed while damaged corn plants tend to be aggregated. Aggregation can be interpreted as having

plots with damage density much greater than the overall mean density while some plots have densities less than the overall mean. Clumped populations, therefore, require careful sampling as there is a danger of taking samples that would give too high or too low estimates of density (Odum, 1971).

The distribution of damaged tillers within rice plants was not random (Tables 4a and 4b). In three of five fields, negative binomial fitted well the observed data; none fitted the Poisson. This may be explained by the rats' tiller-cutting behavior as monitored through infrared CCTV. In 14-week old rice plants, rats investigated the hills first before cutting a particular tiller and not just any available tiller at random. The tillers did not have equal chances of being damaged. The presence of a damaged tiller in a hill even increased the chances of damaging other tillers in that hill. Thus, there were more hills with 3 or more damaged tillers than expected under the Poisson model, if tiller-cutting occurred entirely at random.

Table 4a. Observed frequencies of rat-damaged tillers per hill in farm 3, and their expected frequency under the Poisson and negative binomial models.

Number of Damaged Tillers/Hill	Observed Frequency	Expected Frequency: Poisson	Expected Frequency: Negative Binomial
0	9924	8032.3930	9922.6662
1	644	2953.4708	797.1517
2	432	542.9882	343.5125
3	245	66.5514	188.1719
4	140 (357)[a]	(6.5966)[a]	114.0734
5	85		73.1538
6	49		48.62103
7	30		33.1277
8	18		22.9862
9	6		16.1732
10	15		11.5055
11	5		8.2583
12	3		(22.5986)[a]
13	4		
18	1		
25	1		
Total	11602	11602	11602
Damaged tillers/hill:	$\bar{X}$ = 0.3677 s^2 = 1.4143 I = 2.8463	χ^2 — test: highly significant	highly significant K = 0.102796

[a]Total frequency of remaining classes whose expected frequencies are 5 or less.

In cases where damage extended over a wide range (0 to 25 tillers/hill), neither Poisson nor negative binomial was adequate to describe the data. A more practical index to describe such distribution is the clumping index (I) suggested by David and Moore (1954), namely:

9

$$I = \frac{S^2}{X} - 1$$

The value of I would be close to zero for a Poisson (since $S^2 = X$) and would increase correspondingly with aggregation or clumping. In this study I values were very much greater than 1 (up to 17.1) when neither the Poisson nor the negative binomial gave a satisfactory fit. Anscombe (1950) doubted if any two-parameter distribution like the negative binomial would adequately describe data which show a high degree of clumping.

Table 4b. Observed frequencies of rat-damaged tillers per hill in farm 4, and their expectations under the Poisson and negative binomial models.

Number of Damaged Tillers/Hills	Observed Frequency	Expected Frequency Poisson	Negative Binomial
0	1819	4721.3584	4819.0129
1	110	263.6471	118.7049
2	40 (67)[a]	(7.49453)[a]	34.6138
3	20		13.1734
4	6		(16.459)[a]
5	1		
Total	1996	1996	1996
Damaged tillers/hill:	$\bar{X} = 0.0558$ $S^2 = 0.1111$ $I = 0.9910$	X^2 – test: highly significant	Not significant $k = 0.511$

[a]Total frequency of remaining classes whose expected frequencies were 5 or less.

ACKNOWLEDGMENT

The author would like to thank his adviser Dr. Fernando F. Sanchez, the members of the guidance committee Drs. Mariano B. de Ramos, Bernardo P. Gabriel, and Vicente G. Momongan; Drs. Michael Fall and Isidro David and Prof. Santiago Alviar for their valuable suggestions; Mr. Alberto Eusebio and Miss Florencia Gonzaga for their assistance in computer programming and data analysis; and the U.S. Agency for International Development for partial financial support through the U.S. Fish and Wildlife Service project, "Control of Vertebrate Pests", PASA/RA (ID) 1-67.

LITERATURE CITED

ALLEN, J., D. GONZALEZ, and D.V. GOKHALE. 1972. Sequential sampling plans for the bollworm, *Heliothis zea*. J. Env. Entomol. 1: 771-80.

ANSCOMBE, F.J. 1950. Sampling theory of the negative binomial and logarithmic series distribution. Biometrika 37: 358-382.

10

BARR, A.J., J.H. GOODNIGHT, J.P. SALL and J.T. HELWIG. 1976. A user's guide to SAS. North Carolina: SAS Institute. 329 p.

BATES, J.F. 1963. The cane-field rat in British Guiana and its control. Proc. Intl. Soc. Sugarcane Technol. Corp. 11:695-704.

BLISS, C.I. and R.A. FISHER. 1953. Fitting the negative binomial distribution to biological data and note on the efficient fitting of the negative binomial. Biometrics 9: 176-200.

DAVID, F.N. and P.G. MOORE. 1954. Notes on contagious distributions in plant populations. Ann. Bot. 18:47-53.

DOTY, J.W. 1959. Rodent control in commercial cane areas of Florida Everglades. Proc. Intl. Soc. Sugarcane Technol. Corp. 10:1011-1015.

FALL, M.W. 1975. Vertebrate pests: problems and needs in Nepal. Denver Wildlife Research Center. Unpublished trip report. 18 p.

HARCOURT, D.G. 1956. Sequential sampling for the imported cabbageworm, *Pieris rapae* (L.) Can. Entomol. 93: 741-746.

HOOD, C.A., R.D. NASS, G.D. LINDSEY and D.N. HIRATA. 1971. Distribution and accumulation of rat damage in Hawaiian sugarcane. H. Wildlife Mgt. 35: 613-618.

LINEHAN, J.T. 1957. Measuring bird damage to corn. Proc. Vertebr. Pest Control Conf. 3: 50-56.

MUELLER, E.F. 1970. Field problems of tropical rice. The International Rice Research Institute. 55 p.

OAKLAND, G.B. 1950. An application of sequential analysis to whitefish sampling. Biometrics 6: 59-67.

ODUM, E.P. 1971. Fundamentals of ecology. 3rd ed. Philadelphia: W.B. Saunders. 574 p.

SANCHEZ et al. 1975. Rodent Research Center. 1975 Annu. Prog. Rep. 80 p.

———. 1976 Rodent Research Center. 1976 Annu. Prog. Rep. 100 p.

WATERS, W.E. 1955. Sequential sampling in forest insect surveys. Forest Sci. 1: 68-79.

WATERS, W.E. and W.R. HENSON. 1959. Some sampling attributes of the negative binomial distribution with special reference to forest insects. Forest Sci. 5: 397-412.

WEST, R.R., M.W. FALL, and J.L. LIBAY. 1975. Tiller cutting behavior of rats in growing rice. Phil. Agr. 59: 27-30.

WILLIAMS, J.R. 1953. Field rats on sugar estates and methods for their control. Revue Agr. Sucr. II, Maurice 2: 56-86.