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RODENT DAMAGE AND BURROWING CHARACTERISTICS IN BANGLADESH WHEAT FIELDS

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Abstract: Rat damage to wheat was assessed in 303 fields (196 ha) in 4 districts of Bangladesh. In an appraisal of 515,000 wheat stems, only 0.5% were cut by rats before the booting growth stage. The country-wide rat-damage estimate in mature wheat was 12.1%, or 77,000 tons of grain destroyed before harvest. Wheat damage is attributable primarily to the lesser bandicoot rat (*Bandicota bengalensis*). Damage was highly correlated with stem density. Yield loss and percent rodent damage were also correlated. The average yield for 20 fields was 1,795.9 kg/ha. Seventeen percent of the damaged stems had only the panicle removed, whereas 83% were cut near ground level. Twenty lesser bandicoot rat burrow systems were excavated from the centers of wheat fields. The mean burrow length was 40.2 m, and storage chambers contained as much as 18 kg of cached wheat panicles. Rat damage was correlated with the number of active burrow systems within fields.

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Various vertebrate pest species cause serious crop losses throughout southern Asia, and rodent infestations are a major problem in most field crops. The principal pest rodents in Bangladesh wheat fields are burrowing Muridae, primarily the lesser bandicoot rat (pers. observ.). In addition to what it consumes during the growing season, the rodent digs elaborate underground burrow systems and caches large amounts of grain. Although many farmers complain of considerable loss of rice and wheat in their fields, the present study provides the first information on the magnitude and extent of the losses in Bangladesh.

Wheat production in Bangladesh is becoming increasingly popular among farmers. Between the 1977–78 and 1978–79 crop seasons, the area under cultivation increased from 150,000 to 291,000 ha. The traditional dry-season Boro rice crop (Jan–May) is much more difficult to cultivate because it requires frequent irrigation, most of which is done by hand. Wheat requires little cultivation and watering after broadcasting. Yields over the last 4 years have increased from an average of 1.431 to 1.939 tons/ha, reflecting promotion of adaptable high-yielding varieties.

The objectives of this study were to quantify the extent of rodent damage in wheat, identify which rodent species were causing most of the damage, and determine the effects of stem cutting on yield. The stem is defined as that portion of the plant that gives rise to a panicle (i.e., seed head). Existing methods for damage assessments in wheat are few; however, Bindra and Sagar (1968) examined wheat losses in India, and Khokhar et al. (unpubl. rep., FAO-Vertebr. Pest Centre Working Pap. PAK/71/554, 1979) conducted similar studies in Pakistan.

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Fig. 1. Wheat-producing districts in Bangladesh selected for rat-damage studies.

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METHODS

Eight thanas, 2 from each of the major wheat-producing districts of Dacca, Comilla, Pabna, and Jessore, were selected randomly from district maps, and villages within each thana were numbered (Fig. 1). Four villages were randomly chosen per thana, and as part of a larger study, 2 farmers per village were selected at random and interviewed using a standard questionnaire concerning general vertebrate pest problems. Information was obtained on vertebrate pest species present, crops damaged, crop growth stages damaged, pest control methods used by farmers, grain storage problems, and farmer interest in pest control. Four wheat fields were sampled for each farmer interviewed (8/village), resulting in 256 wheat fields assessed for rat damage. Field size averaged 0.62 ha (range 0.05–1.5 ha), and included various growth stages. An additional 47 fields were sampled as part of other studies: (1) 20 fields examined for the effects of stem cutting on yield, (2) 10 fields assessed in a burrow-damage study, and (3) 17 fields sampled in mature wheat from 2 thanas in the Comilla District, which, when initially examined, had tillering wheat.

Wheat stem density varied among fields depending on the amount of seed broadcast per unit area (recommended 100 kg/ha), quality of seed, type of soil, amount of rainfall or irrigation, and the inconsistent amount of manure or fertilizer applied. Within each wheat field, 10 100 × 50-cm quadrats were examined for rat damage. Two rows of 5 quadrats each were spaced proportional to the length and width of the plot. Total stems and the number of rat-damaged stems were enumerated within each quadrat and the percent damage determined. The outer 1 m of the field perimeter was eliminated because of frequent goat damage.

Field sampling was conducted from December 1978 to April 1979. Each field surveyed was classified according to days after planting. After the stem counts were made, each field was assigned a class relative to the mean stem density per square meter. Forty of the fields sampled during farmer interviews in the Jessore and Pabna districts were examined for differences in damage levels between irrigated and nonirrigated plots. Trapping, fire, flooding, and burrow excavation were used to capture rats to identify the species present.

The effect of rodent stem cutting on wheat yield was evaluated in Gazaria Thana of the Dacca District. Twenty

fields with varying degrees of rat damage were selected. Field dimensions were measured and the length of the diagonal determined. Along 1 diagonal, 5 evenly spaced square-meter quadrats were examined, and the number of cut and uncut stems were counted in each quadrat. These quadrats represented 0.7% of each field sampled. In the first 10 quadrats sampled, 10 panicles from each of the 10 quadrats were randomly picked and placed in plastic bags. The kernels were later removed, counted, dried, and weighed to the nearest gram. The panicles in the remaining 90 quadrats were harvested, placed in bags, and labeled. All were thrashed by hand, sun dried for 8 hours, and weighed to the nearest gram. The observed yield (Y_o) and potential yield (Y_p) were compared for each plot. Potential yield was calculated as

$$Y_p = Y_o(N/n)$$

where n was the number of undamaged panicles, and N was the total number of damaged and undamaged panicles (adapted from Gomez 1972).

Linear regression, correlations, and t tests were used to examine relationships between damage, yield, stem density, and other components of rat–wheat relationships. Mean values are reported as $\bar{x} \pm 1$ SD.

The design and storage characteristics of lesser bandicoot rat burrow systems were examined in 20 separate fields not included in the damage or yield surveys. An 8 × 8-m grid was marked with numbered bamboo sticks above each burrow system examined. Nine rows aligned east–west and labeled A through I were positioned perpendicular to columns numbered 1 through 9. String was stretched between the perimeter stakes during excavations to pinpoint burrow location, and the data were plotted on grid sheets. Plugged and open burrow entrances were counted and the burrow areas classified as tunnel, storage chamber, or nest. Measurements (mm) were taken at about 1-m intervals of linear excavation for burrow diameter and depth (from the ground surface to the top of the burrow). Contents of the storage chambers were identified, air-dried, and weighed to the nearest gram.

Damage was estimated along 4 transects in each of 10 additional fields of Gazaria Thana. Transects were perpendicular to each other, and originated from the outermost burrow entrance in each of 4 directions. At 1-m intervals from the burrow system a 25 × 25-cm wooden frame was placed in the wheat and the total number of cut and uncut stems recorded. If more than 1 surface entrance occurred in a burrow system, 4 random 25 × 25-cm samples were taken from the area among the burrow entrances.

RESULTS

The lesser bandicoot rat was abundant throughout the study area, and 108 specimens were collected. A single greater bandicoot rat (*B. indica*) was collected in the Meghna River floodplain. This species is considerably larger, and averages about 650 g in weight, compared to 200 g for the lesser bandicoot rat; it prefers moister soils and inhabits alluvial areas. Based on the size of burrows observed in wheat fields, the lesser bandicoot rat was the primary rodent species that damaged wheat in Gazaria Thana of the Dacca District. In the Dacca and Pabna districts, 5 soft-furred rats (*Millardia meltada*) were trapped. The species is reputed to damage field crops in much of southern Asia. Soft-furred rats were obtained from sugarcane, soybean, and mustard fields. This 60-g rodent may pose problems in wheat, but the situations we observed were not

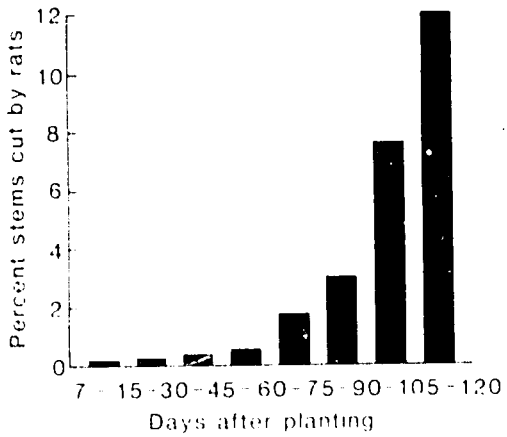

Fig. 2 The accumulation of rat damage in 303 wheat fields in Bangladesh. The wheat growth stages generally correspond to the number of days after planting: tillering 7–60, booting 61–75, flowering 76–90, dough 91–105, and maturity 106–120.

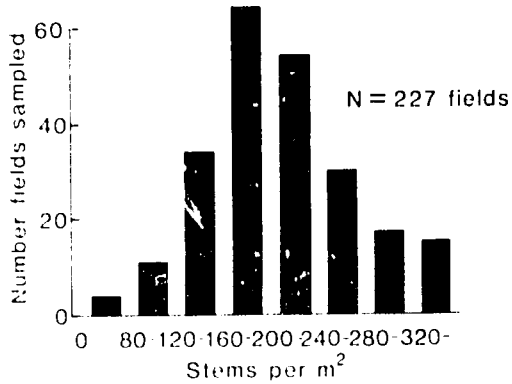

Fig. 3 Frequency histogram of 227 wheat fields sampled according to stem density.

severe. During this study, 1 roof rat (*Rattus rattus arborens*) was killed in a wheat field by a farmer near Laksham, in the Comilla District. According to farmers, this rodent is a pest in wheat, but none was collected during our field trapping. The short-tailed mole rat (*Nesokia indica*) was collected from sugarcane and soybean fields, but none was obtained in wheat plots.

Three hundred three wheat fields, including 315,300 stems, were examined for rat damage. The average percent stems cut for all fields remained under 1% until the crops attained an age of more than 60 days (Fig. 2). Damage increased appreciably at the booting stage, and continued to be severe until the crop was harvested.

Table 1 Rodent damage to mature wheat in Bangladesh

District	No. fields sampled	Total stems sampled	Cut stems	% damage
Dacca	48	58,226	8,[illegible]52	14.0
Comilla	21	28,896	3,[illegible]36	13.0
Pabna	24	24,581	3,073	12.5
Jessore	26	28,743	2,012	7.0
Totals	119	140,446	16,993	12.1

The overall damage in mature wheat for the 4 districts was 12.1% (Table 1). The Dacca District experienced the highest (14%) and Jessore the lowest (7%) damage. Narayanganj Thana of the Dacca District had 15.9% of total stems cut, representing the most severe rat-damage area.

Cut young tillers were generally carried into burrow systems and used as nesting materials by the lesser bandicoot rat. As the crop matured, leaf sheaths were stripped for nests. Caching behavior increased once the crop attained the dough stage, when stems or panicles were cut and carried into the burrows. Most often the stem was cut and the plant felled, then the panicle was removed and cached. In many fields, the lesser bandicoot rat bent the stem over and removed only the panicle, severing it several centimeters below the head.

The frequency of occurrence of stem-density classes for 227 fields sampled from booting to harvest (Fig. 3) revealed that the 161–200-stems/m² class predominated ($N = 64$). Over 50% of the fields had 161–240 stems/m². In general, as the stem density per unit area increased, rat

Table 2. Correlation coefficients for the wheat-damage and rodent-burrow parameters examined

X	Y	N	Regression equation	r
Stem density	Cut stems per m²	119	$Y = 0.1248X - 11.74$	0.98***
No. undamaged panicles per m²	Yield	20	$Y = 0.414X + 436.29$	0.74**
Y_p	Y_f	20	$Y = 1.31X - 151.67$	0.89**
Percent damage	Yield loss ($Y_p - Y_f$)	20	$Y = 12.11X - 85.74$	0.925***
Kernel count	Yield	20	$Y = 0.00123X + 689.46$	0.99***
Burrow entrances	Percent damage	85	$Y^* = 0.63X + 9.72$	0.63*
Burrow systems	Percent damage	85	$Y = 7.89X - 8.15$	0.77**

* [illegible]

damage increased concomitantly (Table 2). Fields with high-yielding varieties and with more manure or commercial fertilizer applications suffered more rat damage than surrounding fields (Fig. 4).

The distribution of damage among fields in a given locality varied with stem density. This was reflected in the yield; fields with denser stems produced more grain per unit area. For example, 1 field with 345 stems/m² had 28% cut, whereas an adjacent plot with 210 stems/m² had only 3% cut. Both fields were sown with high-yielding varieties, but the latter plot had no manure or fertilizer applied. In the yield study, 1 field selected had no rat damage, whereas the highest recorded damage (30%) was observed in a field only 100 m away.

The relationship between the number of undamaged panicles/m² and the corresponding observed yield showed a strong correlation (Table 2). Similarly, correlation was recorded between the observed yield and potential yield for each of the fields (Fig. 5). The reasons for not obtaining a perfect correlation in both analyses are reflected in varietal differences, farmer cultural and management practices, and other field pests and diseases.

A strong relationship between rat-damaged stems (transformed data) (X) and yield loss (Y) was observed ($Y = 12.11X - 85.74$, $r = 0.925$, $P = 0.001$). The total stems sampled per field ranged from 111 to 367 m². Yields in kilograms per hectare averaged 1,795.9, and ranged from 1,024 to 2,238 (Table 3). The 100 panicles examined for kernel counts had a mean kernel count of 38.44 (SD = 12.7) for high-yielding varieties (98% of the total crop). The mean kernel weight was 28.1 mg. Kernel count was highly correlated with the yield in grams. In the yield study, 17% (567) of the wheat stems damaged by rats had only the panicles removed, whereas 83% (2,725) were cut within 10 cm of ground level.

The location and number of burrows and the amount of damage at 1-m intervals away from burrows were examined in 107 fields. Damage was highest between entrances to the same burrow system ($x = 58.1\%$), and ranged from 17 to 85% of all stems.

Lesser bandicoot rat foraging is most intense near the burrow (Fig. 6). An exponential model ($Y = 35.03e^{-0.24X}$) showed a high correlation ($r = 0.952$) with observed data. Observed damage decreased by a factor of 50% beyond 2.5 m. The curve fitted to the data predicted 50% of the damage occurring within 3.3 m. At >10 m damage varied; often the effects of an adjacent burrow system were found within the 10-m transect.

The mean field size for the burrow study was 0.08 ha (SD = 0.26), and there were 3.5 (SD = 2.95) burrow systems per

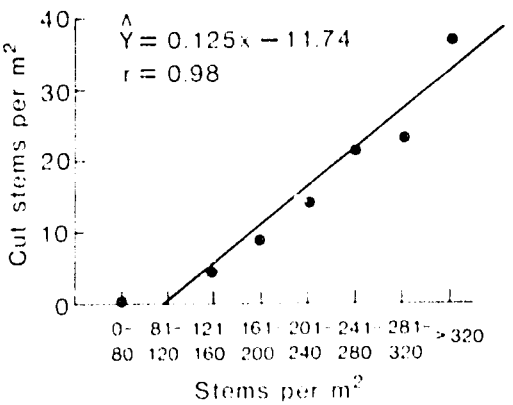

Fig. 4. Regression line for rat damage in wheat fields (cut stems) and stem density ($N = 227$ fields).

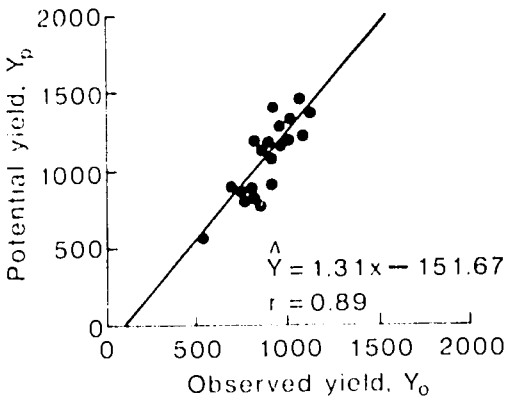

Fig. 5. Regression line indicating the relationship between observed and potential yield in Bangladesh wheat. Y_o is the yield measured in grams/5 m² from harvested grain and Y_p is the amount of wheat that would have been harvested had no rat damage occurred.

field; thus, the mean number of burrow entrances per hectare was 510 (SD = 36.8%). This translates to 1 burrow system/228.6 m² and 1 entrance/19.6 m²; however, these were not necessarily equally distributed over the field. The percent rodent damage in fields ($N = 85$, Table 2) was positively related to the number of burrow entrances and burrow systems. Preliminary observations indicate a stronger relationship between damage and the number of burrow systems than between damage and the number of burrow entrances.

Generally, fresh tracks or loose soil indicated recent activity or use of a burrow entrance. One burrow system excavated near Joydebpur had over 55 m of tunnels. In wheat, most burrows were shallow and ranged from 6.5 to 24 cm in depth (Table 4). During a separate study in rice, however, we uncovered tunnels and caches 1.5 m below the surface (Fig. 7).

The number of branches and the distance between branches were highly variable. In much the same way, dead-end tunnels varied among individual burrow systems. Some served as food caches, whereas others contained nothing. Wheat damage ranged from 0 to 37.6% in the 85 fields examined for the number of burrow systems and corresponding impact of lesser bandicoot rats. The results suggest a strong relationship between the number of burrow systems and the amount of wheat damaged within a field.

Our data suggest that *B. bengalensis* prefers drier soils in wheat fields of the delta region in which to establish its burrow systems. Reduced rat damage was observed in the Jessore and Pabna districts, where fields on government farms were irrigated. Few farmers are financially capable of installing even the most primitive irrigation systems. In compar-

Table 3. Wheat-yield estimates in 20 fields of Gazaria Upazila, Bangladesh. Data were obtained from 5 1-m² quadrats of each field.

	$\bar{x}$	SD
Total stems/m²	256.2	74.2
Uncut stems/m²	223.3	53.1
Cut stems/m²	33.0	30.4
Percent damage	11.0	8.6
Observed yield, Y_o, g/m²	179.6	30.8
Potential yield, Y_p, g/m²	205.0	15.5
Yield loss, $Y_p - Y_o$, g/m²	25.4	23.0
Yield, kg/ha	1,795.9	308.1

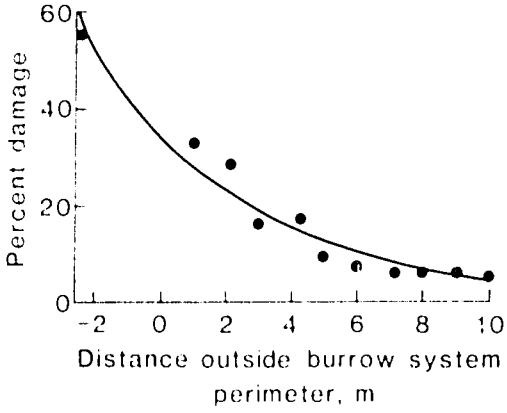

Fig. 6. Rodent damage assessed at 1-m intervals away from the burrow-system center of 107 lesser bandicoot rat burrow systems. Negative distance indicates damage within the burrow system.

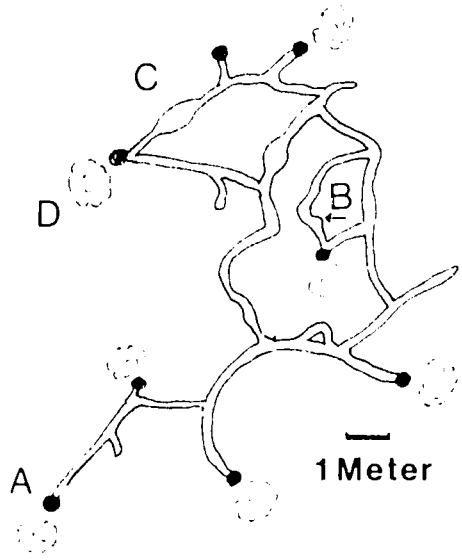

Fig. 7. Sample design (top view) of a lesser bandicoot rat burrow system from a wheat field in the Dacca District. Several components are identified: A, burrow entrance; B, nest chamber; C, storage chamber, and D, pile of loose dirt excavated by rat.

ing 20 irrigated and 20 nonirrigated fields selected at random, mean damage was 1.6 and 9.4%, respectively. The differences in damage levels between 2 was highly significant (t = 3.95, P < 0.01).

DISCUSSION

Rodent damage to wheat in Bangladesh has apparently increased with production over the years, based on subjective observations by government officials. In considering the estimated harvest for 1979 of 565,000 tons, and calculating the 12.1% loss to rodents, about 77,000 tons of wheat were destroyed by rats in the field before harvest.

Table 4. Features of 20 lesser bandicoot rat burrow systems in Bangladesh wheat fields during March and April 1979.

Feature	$\bar{x}$	SD	Range
No. burrow entrances	6.4	3.4	1-16
No. plugged entrances	3.9	3.8	0-12
Total length of burrow	40.2	6.4	33-55
Burrow diameter, mm	76.9	13.5	60-100
Burrow depth, cm	16.7	8.7	6.5-24
No. branches	27.6	7.5	21-56
Distance between branches, m	1.1	1.6	0.2-2.5
No. dead-end tunnels	1.2	3.3	2-14
Length of burrow per entrance, m	6.3	2.1	4-11
No. storage chambers	2.5	1.1	0-7
No. nests	1.5	0.8	0-4
Storage quantity, kg/m burrows containing food	2.4	1.7	0-18
Percent burrows containing food caches	95		

In India, Bindra and Sagar (1968) estimated rat damage in wheat at 2.5%. For the Punjab in Pakistan, Khokhar et al. (unpubl. rep., 1979) computed a total damage index based on diet and trap success, and found the lesser bandicoot rat contributed 13.5% of the damage. In a similar study on rice, Fulk (1977) observed caching behavior in the lesser bandicoot rat, and found about 10% of the crop was hoarded underground. He did not observe significant damage until 2 weeks before harvest, when the plots were drained of irrigation water. Once the soil became dry, bandicoot rats moved into the fields, established burrow

systems, and began storing rice panicles. Our study of wheat revealed similar behavior. Most rats immigrated into fields during the latter stages of crop maturity.

During burrow excavations, an average of 1.5 rats per occupied burrow system were removed from different fields (x = 64 rats/ha). The estimates are for nonirrigated fields because water prevented burrow formation by lesser bandicoot rats inside irrigated fields. Fifty percent of the burrows examined, however, were unoccupied. In 1 field of Gazaria Thana that was flooded, farmers reported killing 80 lesser bandicoot rats in a 35 × 45-m field. This is a density of 508 rats/ha. Falk (1977) estimated a density of lesser bandicoot rats of 300/ha in a rice field with 10% damage.

Although the effects of rat tiller cutting in wheat remain to be studied in detail, several points should be stressed. Rat damage to stems remained visible from 60 days after planting until harvest. Before 60 days the accumulated damage in all districts examined was less than 0.5%, reflecting a minor effect on total yield. The direct impact of stem cutting on yield for wheat older than 60 days showed high correlation ($r = 0.923$), suggesting that damage during the tillering stage may play a minor role in overall yield reduction.

Wheat damage near rat burrow systems revealed heavy feeding within 2.5 m of the burrow openings. Worn runways were noted in heavily damaged fields, some of which linked different burrow systems, but most connected a network of loops leading back to the central burrow.

Data from this study indicate that the lesser bandicoot rat has a preference in locating burrow systems. Higher-yielding fields with high stem densities were used more often than lower-producing plots. Virtually no damage was recorded for plots with less than 80 stems/m², but as the stem density approached 280 stems/m², damage increased to 23%. Plots with a stem density of more than 320/m² had more than 37% of the stems cut. This would imply that fields with higher seeding rates, more soil moisture, or appreciable applications of manure and commercial fertilizers, all of which increase yield, are more prone to rat damage.

Dense wheat fields may attract rats for several reasons. The 1st is a response to better cover; more plants provide rats with more protection. A 2nd possibility is related to energy maintenance. It is more advantageous for a small mammal to reduce its foraging radius by selecting a home range with an optimum supply of food and cover. Reducing the amount of foraging time conserves energy expenditure, reduces the amount of surface activity, and minimizes exposure to predators or conspecifics. Also, greater wheat density may mean greater carrying capacity, larger populations, population compression, and intolerance, and hence, smaller home range.

The rat damage in wheat fields approached 3% about 76 days (booting stage) after planting. Haque et al. (1980) reported that as much as 50% rat damage to wheat stems before this period still produced yields that were not significantly different from those of undamaged plots.

The pattern of damage by lesser bandicoot rats (heavy stem cutting near burrows) indicates that field control operations, using rodenticides, may be more efficient if baits are placed within 1 m of burrow openings rather than randomly in the field. This was suggested by radiotracking studies during the 1980 wheat-growing season in which small, compressed lesser bandicoot rat home ranges

were discerned in fields (Poche et al. 1980*b*). This study and results of a field rodent-control trial (Poche et al. 1980*a*) documented rodent immigrations into fields as the wheat crop matured.

Growth compensation before the booting stage was sufficient to negate significant yield losses. This suggests field baiting may be most efficient and least expensive if it is initiated during the booting stage. Wheat damaged by rats before this growth stage would have sufficient time to recover by compensatory growth.

LITERATURE CITED

BINDRA, O. S., AND P. SAGAR. 1968. Study on the losses of wheat, groundnut and sugarcane crops by the field rats in Punjab. Pages 28–31 *in* Proc. Int. Symp. Bionomics and Control of Rodents, Ranpur, India.

FULK, G. 1977. Food hoarding of *Bandicota bengalensis* in a rice field. Mammalia 41:59–61.

GOMEZ, K. A. 1972. Techniques for field experiments with rice. Int. Rice Res. Inst., Los Banos, Laguno, Philippines. 46pp.

HAQUE, M. E., P. SULTANA, M. Y. MIAN, R. M. POCHE, AND M. A. SIDDIQUE. 1980. Yield reduction in wheat by simulated and actual rat damage. B.A.R.I. Vertebr. Pest Div. Tech. Rep. 9. 19pp.

POCHE, R. M., M. E. HAQUE, M. A. SIDDIQUE, P. SULTANA, M. Y. MIAN, J. DE GRAZIO, AND D. THOMPSON. 1980*a*. Rodent control in wheat fields. B.A.R.I. Vertebr. Pest Div. Tech. Rep. 10. 14pp.

———, M. Y. MIAN, R. STERNER, M. E. HAQUE, AND P. SULTANA. 1980*b*. Rodent movements in wheat fields. B.A.R.I. Vertebr. Pest Div. Tech. Rep. 8. 16pp.

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