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Effectiveness of Four Rodenticides in Deepwater Rice

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(With 3 figures)

Introduction

The tropic and subtropic ecotypes of southern Asia support large populations of field rodents. The impacts of these animals upon most agriculture are well documented (ALAM, 1974; BARNETT & PRAKASH, 1975; DEORAS, 1971; POCHÉ, HAQUE, MIAN & SULTANA, 1982). Self-sufficiency in food production for this region requires improved crop yields through more effective disease and pest control. Effective control of rodent damage is viewed to require adaptation of available methods to the specific cultivation practices of this unique agrosystem.

The river deltas of Bangladesh pose numerous problems to traditional methods of vertebrate pest control. Over one-half of the country (72,000 km^2) floods annually during the summer monsoons. Villages in the floodplain become seasonal islands several meters above water level. Typically, flooding starts in mid to late June, with flood waters covering the farmland until October. The floods force rodents to emigrate low-lying terrain and coexist with villagers on the islands.

Farmers in the delta regions of Bangladesh, India, Thailand, and Vietnam grow substantial amounts of deepwater rice. In Bangladesh approximately 10 million ha of rice (1.9 million ha of deepwater varieties) were cultivated in 1978. These varieties are planted before the monsoons (March - May), and harvested 8 - 10 months later (October - December). As monsoon floods occur, rice stems elongate. The stems contain large air sacs in the mesophyll which permit the plants to float. The distal portion of each stem eventually curves upward, out of the water, until the panicle is from 0.1 to 0.75 m above the surface. Rodents living on islands near the rice swim and move through the floating stems and cut rice plants for food or nest material.

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Data regarding rodent damage to deepwater rice are infrequently reported. CATLING & ISLAM (1979) observed disruption of yield experiments in deepwater rice when rats severely damaged test plots. CATLING (1979) in a similar study reported a 10% reduction in yield attributable to rats.

The objectives of the current study were to: (1) identify rodent species associated with damage to deepwater rice in Bangladesh, and (2) compare the efficacy of four rodenticides in controlling rat populations on island villages during monsoon floods, thereby reducing grain storage losses and rodent damage to adjacent ricefields.

Methods

Study Area

The study was conducted between 10 September and 29 December 1979, in a traditional deepwater rice region within the Bouraganga and Ganges river deltas near the village of Akrakola (approximately 10 km WSW of Dacca, Bangladesh). Five island villages, ranging in size from 0.15 to 3.46 ha served as test sites. Water depths between the islands ranged from 2 to 4 m. Table 1 presents descriptive information for each island.

Table 1
Demographic data characterising the five islands used as test sites

	Islands				
	DRC-4575	Difenacoum	Control	Zn_3P_2	Brodifacoum
Area (ha)	0.15	2.32	2.32	3.14	3.46
Height above flood-plain (m)	3.8	3.9	3.7	3.6	3.7
No. people	31	38	31	110	180
Dwellings	8	6	12	26	48
Kitchen	4	3	4	17	24
Cow sheds	2	3	2	6	9
Cattle	15	16	16	21	25
Goats and sheep	4	1	3	12	14
Poultry	50	55	76	105	45
Storage bins	16	4	9	22	38
Straw/stubble stacks	8	2	3	8	6
Trees	39	16	211	147	278
Bait Boxes	8	8	–	12	12

Rodent Species

Snap traps were used to determine the rodent species composition on islands approximately 0.5 km west of the test islands. An average of 1,725 were set monthly during the study. No removal trapping was performed on the test islands. To discern which rodent species were dispersing onto the deepwater rice and inflicting damage to rice, floating bamboo trap stations were positioned about 0.5 km away from test islands. Trap placement varied from 20 to 200 m away from islands or high ground. Captured rodents were transported to the Vertebrate Pest Division Laboratory, Joydebpur, for positive identification.

Rodenticide Efficacy

The basic procedures used in assessing the effectiveness of rodenticides involved: (1) estimations of the relative abundance of rodents before rodenticide application, and (2) distribution of respective baits and subsequent weekly monitoring of rodent population indices for a 5- or 11-week period. Two islands each were baited for 5 successive -weeks (DRC-4575 and difenacoum). Subsequently, bait was applied on two additional islands (zinc phosphide and brodifacoum) for 10-weeks. One island remained untreated and served as the control throughout the 16-week study.

One week before and once each week during bait applications, a population index of the rodent activity was obtained on each island. A tracking-tile system was used, similar to that described by LORD, VILCHES, MAIZTEGUI & SOLDINI (1970). Twenty-five vinyl floor tiles (30 × 30 cm) were used on each island. One-half of each tile was coated with mimeograph ink and placed at selected locations on the islands. Ten tiles were used inside dwellings, five were placed between dwellings, and ten were spaced along the island periphery. Tiles were positioned at the respective locations on 2 successive nights per week and the number with rodent tracks recorded each morning.

Data from population monitoring were used in determining the efficacy for the four rodenticides. The formula used was:

$$\text{Percent Reduction in Activity} = \frac{\text{Pretreatment Activity} - \text{Posttreatment Activity}}{\text{Pretreatment Activity}} \times 100$$

Table 2 presents detailed information on the rodenticide/bait formulations used on each test island. All baits were placed in 30 × 30 × 15 cm wooden boxes with two 8 × 8 cm entry points for rats. Bait consumption was monitored on a weekly basis. The baits were formulated and stored in 20-mil plastic bags until used. Bait was dispensed at each bait station in

100 g (DRC-4575 and difenacoum) and 200 g (zinc phosphide and brodifacoum) amounts. Bait stations were placed in separate dwellings, and moved to different dwellings every 3 days. After baits had been provided in each dwelling, stations were placed at selected positions along the periphery of the islands.

After baiting was completed, 50 snap traps were set on each island for 2 successive nights, with the distribution of traps similar to that of the tiles.

Table 2

Formulations for the rodenticides used on respective islands

Island	Formulation
1	1% benzenesulfonic acid [(3-amino-2, 4, 6-trichlorophenyl) methylene] hydrazide bait (coded as Denver Research Center No. DRC-4575) contained 1% DRC-4575, 97% rice, 1% coconut oil, and 1% rhodamine B.
2	0.005% difenacoum, 3-(3-p-diphenyl-1, 2, 3, 4-tetra-hydronaphth-1-yl)-4-hydroxycoumarin was prepared by mixing 0.1% difenacoum concentrate at 1:19 with 99% rice, and 1% coconut oil.
3	control. No bait or untreated grain provided.
4	2% zinc phosphide (Zn_3P_2) bait containing 97% whole polished rice, 2% zinc phosphide (94% active ingredient), and 1% coconut oil.
5	0.005% brodifacoum bait 3-[3-(4'-bromo[1-1'-biphenyl]-4-yl)-1, 2, 3, 4-tetrahydro-1-naphthalenyl]-4-hydroxy-2H-1-benzopyran-2-one) was supplied as 6 mm diameter pellets under the trademark TALON. Both difenacoum and brodifacoum were supplied by ICI, Ltd., London.

DRC-4575 contained 1% rhodamine B dye. In the event that dead rats were found in Island 1, autopsies were conducted to verify the cause of death. Rhodamine B is a reddish dye that flouresces pink under ultraviolet light. All of the obtained rat carcasses were examined externally and internally for evidence of marking. The presence of rhodamine B dye on the snout and coat of rats or in the gastrointestinal tract was used as an indication of bait consumption. For a detailed description of rhodamine B procedures, see EVANS & GRIFFITH (1973).

Results and Discussions

Rodent Species

Table 3 presents the trapping results from islands and deepwater rice fields adjacent to the study area. A total of 6,897 snaps traps were set and 86 rodents captured (trap success of 1.25%). From May through December 1979, 721 rodents representing seven species were collected (POCHÉ and

MIAN, 1980). In order of abundance, these included the roof rat *(Rattus rattus)* comprising 51% of the total captures, lesser bandicoot rat *(Bandicota bengalensis)* 28%, house mouse *(Mus musculus)* 19%, greater bandicoot rat *(Bandicota indiga)* 0.5%, softfurred rat *(Millardia meltada)* 0.5%, field mouse *(Mus bodooga)* 0.5%, and the little Burmese rat *(Rattus exulans)* 0.5%.

Before the area flooded, the roof rat was the dominant species on the islands, but the rising waters forced bandicoot rats to immigrate onto the islands. The lesser bandicoot rat then became the dominant species (POCHÉ and MIAN 1980). Before and after water receded, the bandicoot rats *Bandocota spp.* migrated into the fields.

Traps placed on floating bamboo stations in ricefields resulted in the captures of *B. bengalensis* and *B. indica* on floating rice stems (Table 3). Two lesser bandicoot rats were collected 200 m from the islands. The roof rat is apparently confined, for the most part, to the islands. As part of a long-term study, field and island trapping is continuing and no *Rattus* have been obtained from flooded fields. In the Philippines, *Rattus* spp. are a common menace to field crops (BARBEHENN, SUMANGIL & LIBAY, 1973).

Pregnant *Bandicota* were captured in fields over 100 m from land, indicating that normal reproductive patterns continue on the floating environment. Nests were occasionally encountered and were constructed of leaf blades and stems under a dense rice canopy. Two nests were observed over 500 m from the nearest land.

Both *B. indica* and *B. bengalensis* are aggressive species (SPILLET, 1968; FRANTZ, 1973). It is probable that many *Bandicota* disperse onto the floating rice because of the food shortage, but the dispersal may also occur to avoid inter- and intraspecific conflicts on the densely populated islands.

Rodenticide Efficacy

Results of the baiting trials are summarized in Figures 1 and 2. Islands baited with difenacoum and DRC-4575 showed near complete cessation of tracked tiles and bait consumption within 5 weeks, whereas, the zinc phosphide- and brodifacoum-treated islands required 10 weeks. Difenacoum and DRC-4575 bait consumption and population index data declined steadily throughout the 5-week test. Islands treated with zinc phosphide and brodifacoum, however, displayed erratic cycles in bait consumption with consistent decreases in percent tiles tracked.

After a bait box remained in an area for several days, bait consumption declined (Table 4). The box was moved to a new location and rats began to feed heavily for the first few days. The most bait consumption recorded over

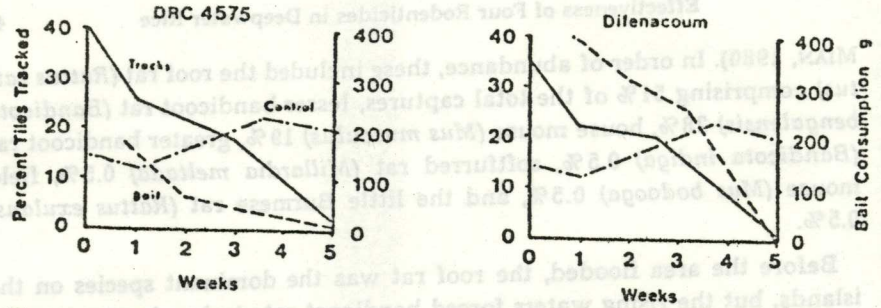

Fig. 1. The relative abundance of five rodent species and bait consumption of DRC-4575 and difenacoum on two islands subjected to a 5-week baiting program from 17 September to 20 October 1979. The relative abundance on the control island is also shown.

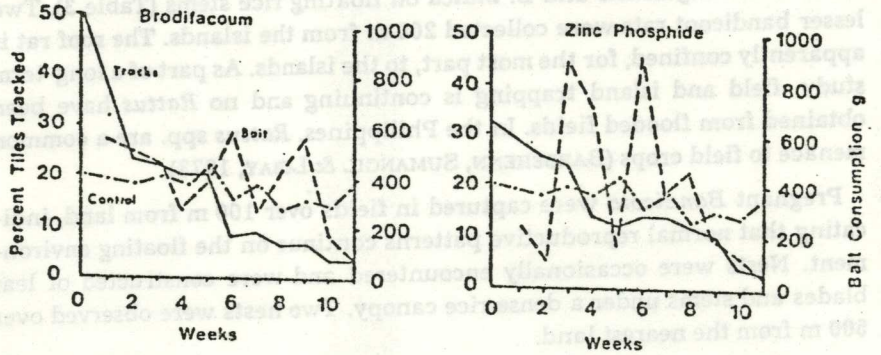

Fig. 2. The relative abundance of five rodent species and bait consumption of brodifacoum and zinc phosphide on two islands subjected to an 11-week baiting program from 15 October to 29 December 1979.

a 7-day period was 854 g of zinc phosphide bait during the sixth week of the study.

Figure 3 presents the response of rodent numbers on the treated islands from three locations on the islands – in and between dwellings, and in scrub along the periphery of the islands. The drop in the relative rodent abundance occurred within 2 weeks on the islands baited with DRC-4575 and brodifacoum. This suggested that rats living in burrows along the island edge, were moving into dwellings at night in search of food. Farmers confirmed this by stating many rats entered the dwellings at night, but lived in burrows near the scrub. Although the tracking tile method is a good means of noting relative abundance, it is difficult and almost impossible in this case, to determine species composition on the islands using tiles alone.

Table 3

Trapping results from the deepwater rice study area in 1979

	Months				
	September	October	November	December	Totals
Removal Trapping[1]					
Trapnights	1 647	1 650	1 750	1 850	6 897
Rodents Captured	30	17	10	29	86
Trap Success	1.82	1.03	0.57	1.57	1.25
Live Traps[2]					
Trapnights[3]	50	60			110
Rodents Captured[4]	5	4			9
Trap Succes	10.0	6.7			8.18
Trapnights	140	140			280
Rodents Captured	3	2			5
Trap Success	2.14	1.42			3.56

1) Snap traps from islands 0.5 Km west of test islands, 2) Traps set in floating rice on bamboo platforms, 3) This Study, 4) 6 *B. indica* and 8 *B. bengalensis*, 5) CATLING (1979).

Table 4

Weekly rodenticide bait consumption (g) on four islands in the deepwater rice floodplain of Bangladesh.

		Weeks										
Island	Rodenticide	1	2	3	4	5	6	7	8	9	10	11
1	DRC-4575	169	61	136	24	0	0					
2	Difenacoum	397	313	285	76	11	0					
3	Zinc phosphide	220	158	852	730	180	854	364	450	198	128	40
4	Brodifacoum	556	471	444	288	380	588	246	404	530	170	92

The efficacy (percent rodent activity reduction) of the four rodenticides was: DRC-4575 – 90.1%, zinc phosphide – 87%, difenacoum – 94.1%, and brodifacoum – 90%. The percent reduction in bait consumption, from the period of highest bait take to the completion of the study was: DRC-4575 – 100%, difenacoum – 100%, zinc phosphide – 95%, and brodifacoum – 84%.

The efficacy determinations for the four rodenticides tested in this study indicated good rodent control with all compounds used. Unlike most field

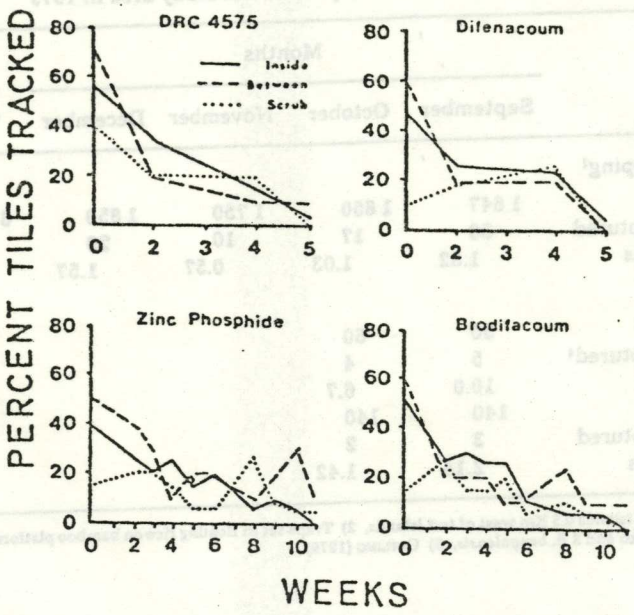

Fig. 3. The relative abundance of five rodent species in three locations on the treated islands (inside dwellings, between dwellings, and along island perifery in scrub) based on a tracking-tile index. These data indicate that rodents occupying burrows along the island edges moved into dwelings nightly and consumed baits.

conditions, the seasonal islands produced by inundation in the deepwater rice zone of Bangladesh are unique in providing confined test populations in which virtually no detectable local migrations are possible for about a 2-month period (July and August). On the final monitoring period of rat activity few tracks were detected.

Snap trapping upon completion of the baiting campaign, resulted in only two rodent captures: one *B. bengalensis* was obtained from the island treated with zinc phosphide and a second was trapped on the brodifacoum baited island (400 trap nights or a combined 0.5% trap success). This was the first time traps were used on the test islands, indicating rodent activity was extremely low.

Dead rats were found on every treated island. On 22 September 1979 within 2 h after placing DRC-4575 bait boxes in dwellings, dead house mice were found on the floor of two buildings. Autopsies revealed ingestion of the chemical as indicated by rhodamine B marking in the mouth, stomach, and small intestines. The forefeet, whiskers, and hairs around the mouth of each mouse also had visible signs of dye.

Outlook for Rodenticide Use

DRC-4575 is a promising rodenticide being tested in the U.S. (MATSCHKE & FAGERSTONE, 1977). Its quick mode of action would be a good asset in convincing farmers and villagers to support a control program, since most people are more confident in a control method that produces dead rats quickly. Several days are required for death to occur with anticoagulant such as warfarin. DRC-4575 is highly toxic to rats but apparently is not very toxic to birds (Anon., 1975). Further examination of the rodenticide is programed and additional field trials will be conducted.

Brodifacoum has proven to be effective, especially in controlling anticoagulant resistant rats. In the U.K., ROWE & BRADFIELD (1976) reported a 91% reduction in *Mus musculus* tracks after treatment, while DUBOCK & KAUKEINEN (1978) observed an 89% decline in Norway rat *(R. norvegicus)* tracks following use of the compound. Our findings indicated a 90% reduction in the tracks of six rodent species, demonstrating similar efficacy to the U.K. studies involving different species.

According to RENNISON & HADLER (1975), difenacoum produced good field control of Norway rats. BROOKS (personal communication), using difenacoum, has succeeded in reducing urban rodent populations in Rangoon, Burma, primarily *B. bengalensis* and *R. exulans*. As the data in our study suggest, field control of rodents in deepwater rice with difenacoum was effective.

Field efficacy determinations for island rat populations also point to zinc phosphide as having potential. A formulation developed in Pakistan by SMYTHE & KHAN (1978) may have possibilities as demonstrated in preliminary laboratory trials in Bangladesh (POCHÉ, SULTANA, HAQUE, and MIAN, 1979). Preliminary laboratory findings have shown zinc phosphide to be effective against *B. bengalensis*, but *R. rattus* from Dacca have demonstrated shyness.

Effective rodent control in Bangladesh deepwater rice is dependent primarily on the use of broad-spectrum rodenticides, since at least seven rodent species have been collected and identified as pests on islands during the monsoons. The species range in size from the 8-g *Mus bodooga* to *B. indica*, sometimes weighing over 800 g. If the objective for control is primarily oriented to field campaigns, then a zinc phosphide formulation may be sufficient. However, if the goal is to control field and grain storage rodent pests, while at the same time address public health problems through rodent control, then other broad-spectrum compounds for which rats do not develop shyness my be more effective.

Rodent control in deepwater ricefields is seldom practiced in Bangladesh. After inundation, field baiting is difficult and time consuming. Bait applica-

tions require the use of boats in fields which generally have dense matt-like layers of long floating rice stems by the time rat damage becomes evident.

After the flowering stage (a function of stem length) boat movements through fields may uproot or break the long rice stems causing more damage to rice plants than rodents. For this reason, farmers are opposed to boat movements in their deepwater ricefields beyond the flowering stage.

Although this study did not demonstrate the impact of island rodent control on the reduction of field rat damage to deepwater rice, the implications suggest an island baiting approach. There is a 2-month period when insufficient floatation is available for the rats to survive solely in the fields and the animals are restricted to the island-villages or higher ground. During this time, rodents are quite vulnerable to control. Since wheat and beans are the major crops harvested before the deepwater rice is planted in March and April, grain stocks on the islands have been sold or begin to run low by mid to late summer. The natural food supply for rodents on the islands or higher terrain, such as grasses and herbs, is quickly consumed by domestic livestock which crowd onto the little available space with man. Bait acceptance then increases appreciably because little other of food is available.

Baiting during this period of restriction on the higher ground should reduce the rodent numbers, some of which would eventually move out to the field about the flowering stage, and others when the floods begin to recede. Rat damage should, therefore, be reduced. However, a rodent control program in deepwater rice should be conducted on a large scale to reduce rat numbers in a given area. MIAN (unpublished data) noted little difference in field damage patterns or the number of stems cut, if only selected islands were treated while neighboring villages remained untreated. If a total approach is not taken, sufficient rodents from untreated islands may disperse into the fields and damage rice plants.

According to CATLING (1979) although rodent damage occurs during the flood period when rats are living on the floating rice, more damage is inflicted when the flood waters recede and additional rats from the islands return to the fields before the crop is harvested. If floods drop abruptly and areas in the fields become dry, the bandicoot rats cut and cache stems in burrow systems they quickly establish in drier areas. HAQUE, SULTANA, MIAN, POCHÉ & SIDDIQUE (1980) observed 2 lesser bandicoot rats cut 3,127 wheat stems over a 15-day period, illustrating how little time rats require to wreak havoc to fields crops.

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Summary

Approximately one-half of Bangladesh floods annually during the summer monsoons forcing field rodents to migrate to villages, which are then distinct islands in the floodplain. Rodent species identified on the islands were *Bandicota bengalensis, Bandicota indica, Rattus rattus, Rattus exulans, Millardia meltada, Mus musculus,* and *Mus bodooga.* Four rodenticides were tested during the period when rats are confined to islands. One-percent benzenesulfonic acid hydrazide (DRC-4575), 0.005% difenacoum, 2% zinc phosphide, and 0.005% brodifacoum baits were provided on separate islands. Reduction of rat activity on the treated islands was: DRC-4575 – 90.1%; difenacoum – 94.1%, zinc phosphide – 87%, and brodifacoum – 90%.

Field observations indicated the best period for baiting the islands is during the first 2 months after the onset of flooding when rodents are restricted to smaller areas – island villages. After this period both species of *Bandicota* swim out into fields and live on floating stems of deepwater rice in water to 4 m deep. Once rats disperse from the islands control becomes difficult in deepwater ricefields.

Zusammenfassung

Ungefähr die Hälfte der Landfläche von Bangladesch wird während des Sommermonsuns überflutet und zwingt die im Feld lebenden Nagetiere (7 Arten) in die Dörfer zu wandern, die wie Inseln aus dem Überflutungsgebiet herausragen. Mehrere Rodentizide wurden zu ihrer Bekämpfung angewendet, wenn die Feldnager auf den „Inseln" zusammengedrängt leben. Feldbeobachtungen zeigten, daß die Giftlegungen am wirksamsten waren, wenn sie in den ersten beiden Monaten der Überflutung erfolgten. Danach wandern die beiden *Bandicota*-Arten *(B. bengalensis* u. *B. indica)* schon wieder ab und sind dann wesentlich schwerer in den Reisfeldern zu erreichen.

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