Hindawi Publishing Corporation
Advances in Zoology
Volume 2014, Article ID 565306, 9 pages
http://dx.doi.org/10.1155/2014/565306

Research Article

Efficacy of Germinated Cereals as Bait Carrier for Zinc Phosphide and Bromadiolone against Field and Commensal Rodent Pests: A Laboratory Evaluation

P. Sakthivel[1,2] and P. Neelanarayanan[1]

[1] *Research Department of Zoology, Nehru Memorial College (Autonomous), Puthanampatti, Tiruchirappalli District, Tamil Nadu 621 007, India*
[2] *National Institute of Plant Health Management, Rajendranagar, Hyderabad 500 030, India*

Correspondence should be addressed to P. Sakthivel; ratsakthi@yahoo.com

Received 23 April 2014; Revised 14 July 2014; Accepted 18 July 2014; Published 7 August 2014

Academic Editor: Lorena Rebecchi

Both sexes of rodent pests such as *Bandicota bengalensis, Millardia meltada, Mus booduga,* and *Rattus rattus* were subjected to toxicity tests (acute rodenticide: 1.5% and 2% zinc phosphide and chronic rodenticide: bromadiolone (0.005%), under no-choice and choice tests) by using their preferred germinated cereals, namely, paddy, pearl millet, and finger millet, as bait base, individually. The results indicated that the poison baits in the germinated cereals induced all the chosen four species of rodent pests to consume greater quantities of bait perhaps due to the bait carrier's palatability and texture. Besides these, the chosen three germinated cereals proved themselves that they are also capable of acting as suitable bait base for both selected rodenticides in bringing maximum mortality among the tested rodent pests under both no-choice and choice tests. Therefore, these germinated cereals may be recommended as a bait carrier for both zinc phosphide (2%) and bromadiolone (0.005%) poisons for the control of all these four species of rodent pests under field conditions. However, this requires field based trials with rodenticides for making a final recommendation.

1. Introduction

Rodents are economically important organisms and some of them are reported to be serious pests destroying crops, fruit gardens, orchards, and stored food grains. Moreover, they cause damage to the properties of various kinds belonging to men which results in huge economic losses. They have a high breeding rate and many show periodic increase in the population which coincides with the availability of food [1]. In India, they are responsible for 10–15% of loss to total national produce [2].

In Tamil Nadu, four species of field rodent pests are found in *Cauvery* delta, "the Granary of South India." According to Sivaprakasam and Durairaj [3], Neelanarayanan et al. [4], and Neelanarayanan [5] the rodent pests such as *Bandicota bengalensis*, *Millardia meltada,* and *Mus booduga* are known to inhabit the crop fields and *Tatera indica* is found in barren lands around the crops fields. Neelanarayanan [5–7] and Neelanarayanan et al. [4, 8–11] reported that these rodent pests inflict damage to different stages of various crops of this area. Brown rats (*Rattus norvegicus*) and house mice (*Mus musculus*) along with the roof rats (*Rattus rattus*) are known as commensal rodents; that is, they are usually found in association with humans.

Rodents also pose a serious health risk as transmitters of several diseases to human and domestic animals such as leptospirosis, salmonellosis, trichinosis, hantavirus pulmonary syndrome, hantavirus renal syndrome, Argentine hemorrhagic fever, and lymphocytic choriomeningitis [12–14]. Commensal rodents can carry many diseases transmissible to humans [15]. Some of them, such as plague, are carried mainly by noncommensal rodents and may have to be passed into a commensal species before they can become important in public health field [16]. Thus, it becomes indispensable to bring down the population of both crop field and commensal rodents in animal husbandry and human environments to minimize these health risks. Several methods are being employed by farmers to control the rodent pests, such as cultural methods (habitat management, clean cultivation), physical methods (burrow digging, rat hunting by men), mechanical methods (trapping), biological methods (using biological agents such as predators/parasites), nonlethal agents (repellents), and chemicals (rodenticides). Poisoning or chemical control is the most common, expedient, and humane method to control rodent populations. Rodents often prefer soft or finely divided foods to harder and coarser ones. Earlier, Carlson, and Hoelzel [17] reported that the laboratory rats tended to eat the softer parts of grains and to leave the harder parts, and on the other hand they stated that if the grains were soaked in water, they were eaten whole. Soaking, however, may influence taste, through the formation of sugars. According to Sridhara [18] food selection among rodents is influenced by energy value, water content, physiological effects, and flavour of the food. Further, she opined that the rodent control measures could be successful only with the poison baits that are readily accepted by the target species. The preferred bait carrier (nongerminated grains in different forms) for 14 species of rodent pests under laboratory conditions has been compiled and reported by Prakash and Mathur [19].

From the literature review it is understood that there is no published information on the preferred germinated grains' use as bait base under laboratory situations and hence the present study was designed with the following objectives: to study and record the mortality rate of four species of rodents (individually) by using the most preferred germinated bait bases (paddy, pearl millet, and finger millet) at 1.5% and 2% concentrations of zinc phosphide and 0.005% concentration of bromadiolone (independently) under laboratory conditions under both no-choice and bi-choice tests.

2. Materials and Methods

2.1. Procurement of Test Animals. Three species of field rodent pests, namely, *B. bengalensis*, *M. meltada,* and *M. booduga,* which are found in the crops fields of *Cauvery* delta, South India and one species of commensal rodent, *R. rattus*, which is a serious pest in grain godowns, houses, and shops, were chosen as test animals for the present study. The first three field rodent pests were live trapped with the help of traditional rodent trappers from the nearby crop fields in and around Puthanampatti villages, Tiruchirappalli district, Tamil Nadu, India, by burrow digging method as suggested by Sivaprakasam and Durairaj [3]. They were brought to the laboratory, weighed, sexed, and lodged in individual cages (60 cm × 30 cm × 30 cm). They were placed in the live animal keeping rooms of the Rodent Laboratory of our college. The commensal rats (*R. rattus*) were trapped alive from residential, office, godowns, and hostel premises in and around Kottathur and Puthanampatti villages, Tiruchirappalli district, Tamil Nadu, India, by using wooden live traps and wonder traps. These traps were set with bait in the evening and placed on the runways of rats [20]. In order to avoid trap shyness for wooden traps, the traps were set in "off" position for first two days with chosen baits placed inside the traps and on the third day onwards they were set in "on" position [21]. In the next day morning the traps were checked and the trapped rodents were brought to the laboratory to be weighed, sexed, and lodged in the rodent cages.

2.2. Acclimation of Experimental Animals. The individually lodged animals in rodent cages were acclimatized to laboratory conditions for ten days. During this period *ad lib* quantities of nongerminated paddy and water were provided to them. For each set of experiments ten healthy animals (5 males + 5 females), individually, were used.

2.3. Toxicity Tests. Zinc phosphide (1.5 and 2%), an acute rodenticide, and bromadiolone (0.005%), chronic rodenticide powder formulations, were chosen for the present study to evaluate their efficacy by using germinated cereals as poison bait carrier against rodents under laboratory conditions. The acute toxicity studies were carried out with two different concentrations of zinc phosphide, that is, 2% for *B. bengalensis* [22] and 1.5% for *M. meltada* [23] and *M. booduga*. However, Prakash [24] recommended zinc phosphide at 2% for all rodents in general, including *R. rattus*. The bromadiolone was used at 0.005% concentration.

The grains preferred by the test animals under two-choice and multiple choice tests, namely, germinated paddy, pearl millet, and finger millet and because of their low cost and easy availability when compared to pulses, were used as bait carrier for the chosen rodenticides as suggested by Sakthivel [25], Sakthivel and Neelanarayanan [26], and Sakthivel et al. [27]. These tests were conducted under both no-choice and choice conditions, individually. All these tests were conducted by following the method suggested by Baskaran et al. [28].

2.3.1. No-Choice Tests. In these tests, no optional food was given to the experimental animals and they were fed only with poison bait prepared individually. Both poison baits were prepared in the following proportions: 96 g of germinated cereals (paddy/pearl millet/finger millet) mixed with 2 g of zinc phosphide poison/2 g of bromadiolone and 2 gram of coconut oil. The 1.5% concentration of zinc phosphide was prepared by mixing 97 g of germinated cereals (paddy, pearl millet and finger millet), 1.5 g of zinc phosphide and 1.5 g of coconut oil. All the caged animals were famished for 24 hrs before being offered with poison bait. Then, each caged rodent was offered a cup of 20 g poison bait and a cup of water. At the end of every 24 hours, poison bait consumption was recorded, individually. In order to calculate the hours to death as far as zinc phosphide is concerned the experimental animals were inspected every one-hour interval and mortality rate was calculated. As far as bromadiolone poison bait is concerned the bait was offered for two consecutive days and same was replenished at 24 hrs interval. The animals fed with bromadiolone were inspected once in 24 hrs and the days to death were calculated and recorded.

Table 1: Mortality of four rodent species after feeding on zinc phosphide (1.5%–2%) baits of germinated cereals in no-choice tests.

Species	Conc. (% a.i. in bait)	Bait (germinated form)	Body weight (g) mean ± SD[a]	Poison consumption (g/100 g body wt.) mean ± SD[a]	Mortality	Hours to death mean ± SD[a]
B. bengalensis	2%	Paddy	104.5 ± 14.2 (88–135)	4.54 ± 0.44 (2.56–5.31)	10/10	11.8 ± 3.9 (6–18)
	2%	Pearl millet	150.9 ± 28.6 (114–196)	1.84 ± 0.40 (1.12–2.79)	10/10	4.0 ± 0.5 (3.5–5)
	2%	Finger millet	115.6 ± 37.3 (73–165)	1.94 ± 0.63 (1.21–2.8)	10/10	3.2 ± 0.6 (2.5–4.5)
M. meltada	1.5%	Paddy	39.7 ± 8.6 (33–60)	5.47 ± 2.48 (3.74–12.0)	10/10	9.1 ± 4.0 (4–17)
	1.5%	Pearl millet	44.5 ± 7.3 (35–55)	1.6 ± 0.5 (0.4–2.5)	10/10	6.4 ± 1.9 (5–11)
	1.5%	Finger millet	43.9 ± 5.9 (35–52)	1.4 ± 0.6 (0.6–2.2)	10/10	6.8 ± 2.3 (4–12)
M. booduga	1.5%	Paddy	7.3 ± 0.6 (6.7–8.5)	14.31 ± 3.77 (9.28–24.1)	9/10	7.6 ± 3.7 (0–14)
	1.5%	Pearl millet	7.1 ± 0.4 (6.7–7.8)	1.9 ± 0.7 (0.5–2.7)	10/10	5.20 ± 1.2 (3.5–7)
	1.5%	Finger millet	8.5 ± 0.4 (7.8–9)	5.08 ± 4.47 (1.66–14.37)	10/10	4.6 ± 1.0 (3.5–6)
R. rattus	2%	Paddy	94.2 ± 16.1 (58–112)	6.16 ± 2.20 (4.25–9.79)	10/10	7.6 ± 3.1 (4–12)
	2%	Pearl millet	89.9 ± 16.6 (65–114)	3 ± 1.0 (1.9–5.5)	10/10	5.1 ± 1.2 (4–8)
	2%	Finger millet	98 ± 11.9 (75–112)	1.9 ± 0.8 (0.30–3.9)	9/10	7 ± 2.8 (6–11)

[a]Mean and standard deviation values were obtained from observation of ten animals in each test (numbers in brackets are the range values).

2.3.2. Choice Tests. All the caged animals were starved for 24 hrs before being fed with poison bait. Then, 20 g of poison prepared in the germinated cereals and 20 g of plain bait (its counterpart in nongerminated form—as the alternative food does not exist in germinated form in field situations) along with a cup of water were offered to the caged rodents, individually.

The baits were offered 24 hrs for zinc phosphide and 48 hrs (two consecutive days) for bromadiolone, for both no-choice and two-choice tests. The survived rodents were provided with plain bait for 72 hrs for zinc phosphide fed rodents and 14 days for bromadiolone rodents. All the baits were replenished with fresh bait once in 24 hrs. At the end of every 24 hours, poison/plain bait consumption was recorded. All these experiments were carried out from January 2007 to December 2007.

2.3.3. Statistical Analysis. All the data were analysed by using SPSS version 16.0 as described by Rajathi and Chandran [29]. Data were subjected to t-tests (two-tailed) to establish significant differences in consumption between germinated poison bait and nongerminated plain bait for zinc phosphide poisoning under choice tests. Paired "t" test was used to find the difference between the poison bait consumption on first and second days under no-choice tests and poison and plain bait ingestion by the experimental animals (bi-choice tests) under laboratory conditions for bromadiolone poisoning.

3. Results and Discussion

3.1. Acute Toxicity Tests: No-Choice Tests. The results of no-choice tests on acute toxicity studies with four species of rodents fed with different geminated cereals (paddy, pearl millet, and finger millet) mixed with zinc phosphide are provided in Table 1.

3.1.1. The Lesser Bandicoot Rat (B. bengalensis). The maximum poison consumption by the test animals was germinated paddy (4.54 ± 0.44 g/100 g body wt.) and minimum for pearl millet (1.84 ± 0.40 g/100 g body wt.). Cent percent mortality of *B. bengalensis* was observed on feeding with 2% concentration of zinc phosphide prepared by using all germinated cereals. Mean hours to death of experimental animals were 11.8 ± 3.9 (paddy), 4.0 ± 0.5 (pearl millet), and 3.2 ± 0.6 (finger millet) (Table 1).

3.1.2. The Soft-Furred Field Rat (M. meltada). The poison consumption by the test animals was found to be maximum for bait prepared by using germinated paddy

Table 2: Mortality of four species of rodents after being fed on zinc phosphide (1.5%–2%) baits of germinated cereals in choice tests.

Species	Concentration (% a.i. in bait)	Bait	Body weight (g) mean ± SD[a]	Intake (g/100 g body wt.) mean ± SD[a]		P value[b]	Mortality	Hours to death mean ± SD[a]
				Plain (nongermi)	Poison (germi)			
B. bengalensis	2%	Paddy	92.1 ± 15.7 (68–113)	4.3 ± 1.61 (2.56–7.94)	2.42 ± 1.83 (1.70–7)	0.002**	9/10	7.2 ± 4.1 (5–17)
	2%	Pearl millet	129.9 ± 21.4 (98–170)	5.51 ± 2.96 (1.66–10.2)	1.3 ± 0.97 (0.81–2.5)	0.000***	10/10	10.05 ± 5.1 (4–18)
	2%	Finger millet	137.3 ± 19.4 (115–170)	3.77 ± 1.29 (0.80–7.87)	1.07 ± 0.46 (0.38–1.81)	0.035*	10/10	10.3 ± 5.8 (4–18)
M. meltada	1.5%	Paddy	38.7 ± 6.1 (34–55)	1.40 ± 1.07 (0.10–3.50)	5 ± 2.4 (2.3–10)	0.215[NS]	10/10	5.2 ± 2.8 (3–11)
	1.5%	Pearl millet	47.9 ± 5.9 (40–56)	1.5 ± 0.8 (0–2.2)	7.8 ± 2.5 (1.8–13.2)	0.000***	7/10	5.8 ± 4.2 (6–12)
	1.5%	Finger millet	40.6 ± 6.6 (32–51)	2.6 ± 1.4 (0.7–4.8)	2.4 ± 1.8 (0–6.8)	0.470[NS]	8/10	6.6 ± 4.1 (5–12)
M. booduga	1.5%	Paddy	7.7 ± 0.7 (6.8–9.1)	8.07 ± 5.21 (3.4–21.9)	16.66 ± 4.58 (10.4–25.1)	0.791[NS]	9/10	11 ± 4.7 (8–17)
	1.5%	Pearl millet	9.3 ± 1.6 (6.8–12)	8.5 ± 3.63 (3.3–11.8)	3.62 ± 2.14 (0.58–7.5)	0.865[NS]	10/10	8.8 ± 3.2 (4.5–16)
	1.5%	Finger millet	8.9 ± 1.6 (8–11)	8.5 ± 11.63 (1.3–41.8)	3.62 ± 2.14 (1.58–7.5)	0.085[NS]	9/10	6.5 ± 4.7 (4–18)
R. rattus	2%	Paddy	98.9 ± 20.4 (58–135)	4.27 ± 1.63 (1.11–6.73)	4.17 ± 1.07 (3.16–4.31)	0.913[NS]	10/10	8.7 ± 2.6 (5–14)
	2%	Pearl millet	89.9 ± 16.6 (65–114)	2.9 ± 0.6 (2.0–4.2)	5.7 ± 2.9 (1.9–11)	0.014**	10/10	5.7 ± 1.2 (4–8)
	2%	Finger millet	98 ± 11.9 (75–112)	2.0 ± 0.8 (1.3–3.6)	4.9 ± 2.6 (0.6–8)	0.006*	10/10	10 ± 2.4 (7–14)

[a]Mean and standard deviation values were obtained from observation of ten animals in each test (numbers in brackets are the range of values).
[b]The difference between poison and plain bait intake is statistically significant based on paired "t" test. $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; $^{NS}P > 0.05$.

(5.47 ± 2.48 g/100 g body wt.) and minimum for finger millet (1.4 ± 0.6 g/100 g body wt.). Hundred percent mortality of *M. meltada* was observed on feeding with 1.5% concentration of zinc phosphide prepared by using all germinated cereals. Mean hours to death of experimental animals were 9.1 ± 4.01 (paddy), 6.4 ± 1.9 (pearl millet), and 6.8 ± 2.3 (finger millet) (Table 1).

3.1.3. The Indian Field Mouse (M. booduga). The highest poison consumption by the test animals could be observed for the bait prepared by using germinated paddy (14.31 ± 3.77 g/100 g body wt.) and lowest for pearl millet (1.9 ± 0.7 g/100 g body wt.). Hundred percent mortality of *M. booduga* was observed on feeding with 1.5% concentration of zinc phosphide prepared by using two germinated cereals, namely, pearl millet and finger millet. Mean hours to death of experimental animals were 7.6 ± 3.7 (paddy), 5.2 ± 1.2 (pearl millet), and 4.6 ± 1.0 (finger millet) (Table 1).

3.1.4. House Rat (R. rattus). The high intake of poison by the test animals was recorded in germinated paddy (6.16 ± 2.20 g/100 g body wt.) and less in finger millet (1.9±0.8 g/100 g body wt.). Cent percent mortality of *R. rattus* was observed on feeding with 2% concentration of zinc phosphide prepared by using germinated cereals such as paddy and pearl millet. Hours to death of experimental animals ranged between 4 and 12 hours irrespective of the germinated cereals used in the bait (Table 1).

The results under no-choice tests revealed that hundred percent mortality was observed in all four species of rodents on feeding with zinc phosphide baits mixed with germinated cereals. However, 90% mortality was observed in *M. booduga* (feeding with zinc phosphide in germinated paddy) and *R. rattus* (feeding with zinc phosphide in germinated finger millet).

3.2. Acute Toxicity Tests: Choice Tests. The results of choice tests on acute toxicity studies with four species of rodents fed with different geminated cereals (paddy, pearl millet, and finger millet) mixed with zinc phosphide are given in Table 2.

3.2.1. Lesser Bandicoot Rat (B. bengalensis). The experimental animals were found to feed more quantity of plain bait than the poison bait and the difference between them was found to be statistically significant ($P < 0.05$; 0.01; 0.001). However, cent percent mortality of test animals could be observed only with the animals fed on the bait prepared by using pearl millet

Table 3: Mortality of four rodent species after feeding on 0.005% bromadiolone baits of germinated cereals for two days in no-choice tests.

Species	Bait	Body weight (g) mean ± SD[a]	Poison consumption (g) mean ± SD[a]		Intake of active ingredient (mg/kg^{-1}) mean ± SD[a]		Mortality	Days to death mean ± SD[a]
			1st day	2nd day[b]	1st day	2nd day		
B. bengalensis	Paddy	104.1 ± 30.2 (65–165)	11.7 ± 1.8 (7.7–14)	10.1 ± 2.3^{NS} (8–14.2)	6.1 ± 2.2 (3.0–10.9)	6.6 ± 4.7 (3.2–19.2)	10/10	5.2 ± 2.5 (1–9)
	Pearl millet	118.7 ± 18.1 (92–148)	10.8 ± 1.03 (8.8–12.0)	8.7 ± 1.6** (4.5–10)	4.6 ± 0.7 (3.40–5.8)	3.8 ± 1.0 (1.5–5.4)	10/10	2.1 ± 0.5 (1–3)
	Finger millet	111.3 ± 13.7 (92–135)	9.2 ± 1.4 (7.5–12.9)	5.8 ± 1.6** (2.1–8)	4.16 ± 0.6 (3.3–5.1)	5.8 ± 1.6 (2.1–8)	10/10	3.4 ± 0.8 (2–5)
M. meltada	Paddy	42.5 ± 5.27 (35–52)	7.13 ± 2.8 (2.3–11.3)	8.9 ± 3.3^{NS} (1.3–14.2)	8.5 ± 2.8 (3.7–12.6)	10.4 ± 3.8 (1.5–14.5)	7/10	4.6 ± 2.5 (1–8)
	Pearl millet	39.2 ± 3.85 (32–45)	7.1 ± 1.0 (5–8.2)	6.7 ± 2.5^{NS} (1–10)	9.2 ± 1.8 (6.7–12.8)	6.7 ± 2.5 (1–10)	9/10	8.5 ± 4.1 (6–14)
	Finger millet	41.3 ± 4.7 (32–52)	5 ± 1.3 (3.6–7.2)	6.7 ± 1.2** (5–8.5)	5.9 ± 1.6 (4.0–8.9)	7.90 ± 1.2 (5–8.5)	10/10	8.2 ± 2.2 (5–12)
M. booduga	Paddy	8.07 ± 1.0 (6.5–9.5)	2.3 ± 0.4 (2–3.1)	1.6 ± 0.2** (1.2–2)	14.8 ± 3.7 (10.7–21.8)	11.4 ± 2.4 (6.5–14.9)	10/10	3.6 ± 1.5 (2–6)
	Pearl millet	9.7 ± 1.5 (7–12.15)	2.4 ± 0.8 (1–3.2)	1.8 ± 1.0* (0–3.0)	12.6 ± 5.1 (2.7–18.5)	9.6 ± 5.7 (0–17.6)	9/10	3.4 ± 1.7 (2–6)
	Finger millet	10.3 ± 1.3 (8.5–12.1)	2.50 ± 0.3 (2–2.9)	2.3 ± 1.0^{NS} (0.8–3.8)	12.2 ± 1.9 (8.9–14.7)	11.5 ± 5.6 (3.4–22.3)	10/10	4.4 ± 3.9 (1–11)
R. rattus	Paddy	75.4 ± 14.6 (50–101)	8.5 ± 1.5 (6.5–11)	11.4 ± 3.0* (5–14)	5.8 ± 1.7 (4.1–9.3)	8.1 ± 3.2 (2.4–13.1)	6/10	3.6 ± 3.8 (3–11)
	Pearl millet	96.9 ± 9.5 (80–111)	9.7 ± 1.0 (8.5–11.5)	8.2 ± 0.9* (7–10)	5.0 ± 0.7 (4.1–6.7)	4.2 ± 0.4 (3.5–5.0)	10/10	7.3 ± 1.8 (5–11)
	Finger millet	9.4 ± 1.2 (7.64–11)	9.4 ± 1.2 (7.6–11.2)	7.1 ± 1.0* (5.8–8.8)	5.1 ± 0.5 (4.3–5.7)	3.9 ± 0.6 (2.9–4.7)	10/10	10.7 ± 2.5 (7–14)

[a]Mean and standard deviation values were obtained from observation of ten animals in each test (numbers in brackets are the range of values).
[b]The difference between the poison bait consumption on first and second days is statistically significant (paired "t" test). $^{*}P < 0.05$; $^{**}P < 0.01$; $^{NS}P > 0.05$.

and finger millet. Hours to death of experimental animals ranged between 4 and 18 (Table 2).

3.2.2. Soft Furred Field Rat (M. meltada). All the *M. meltada* were found to feed more quantity of poison bait than the plain bait; however, the difference between them (paddy and finger millet) was found to be statistically insignificant ($P > 0.05$). Cent percent mortality of test animals could be observed only with the animals fed on the bait prepared by using paddy. Hours to death of experimental animals ranged between 3 and 12 (Table 2).

3.2.3. Indian Field Mouse (M. booduga). Although the experimental animals were found to feed more quantity of poison bait (paddy) than the plain bait, insignificant difference was observed between them ($P > 0.05$). Hundred percent mortality of test animals could be observed only with the animals fed on the bait prepared by using pearl millet. Hours to death of experimental animals ranged between 4 and 18 (Table 2).

3.2.4. House Rat (R. rattus). The experimental animals were found to feed more quantity of poison bait than the plain bait and the difference between them was found to be statistically significant ($P < 0.05$: finger millet; $P < 0.01$: pearl millet). Cent percent mortality of test animals could be observed with the animals fed on the bait prepared by using all the three cereals. Hours to death of experimental animals ranged between 4 and 14 (Table 2).

Under choice tests, cent percent mortality of rodents was observed in *B. bengalensis* (fed with zinc phosphide bait prepared by using germinated pearl millet and finger millet), *M. meltada* (fed with zinc phosphide bait by using germinated paddy), *M. booduga* (fed with zinc phosphide bait by using germinated pearl millet), and *R. rattus* (fed with zinc phosphide bait by using germinated paddy, pearl millet, and finger millet).

3.3. Chronic Toxicity Tests: No-Choice Tests. The results of no-choice tests on chronic toxicity studies with four species of rodents fed with different geminated cereals (paddy, pearl millet, and finger millet) mixed with 0.005% bromadiolone on two days exposure are provided in Table 3.

3.3.1. Lesser Bandicoot Rat (B. bengalensis). The difference between the poison bait intake on first and second days was found to be statistically significant for pearl millet and finger millet ($P < 0.01$). The highest intake of active ingredient (mg/kg^{-1}) in the test animals was 6.6 ± 4.7 on the second day of feeding (paddy bait). Cent percent mortality of *B. bengalensis* was observed on feeding with 0.005% concentration of bromadiolone prepared by using all germinated cereals. Mean days to death of experimental animals were 5.2 ± 2.5 (paddy), 2.1 ± 0.5 (pearl millet), and 3.4 ± 0.8 (finger millet) (Table 3).

3.3.2. Soft-Furred Field Rat (M. meltada). It is evident from Table 3 that significant difference could be observed between the poison bait intake on the first and second days for paddy and finger millet ($P < 0.01$). The highest intake of active ingredient (mg/kg^{-1}) in the test animals was 10.4 ± 3.8 on the second day of feeding (paddy bait). Cent percent mortality of *M. meltada* was observed. Mean days to death of experimental animals were 4.6 ± 2.5 (paddy), 8.5 ± 4.1 (pearl millet), and 8.2 ± 2.2 (finger millet) with an overall range of 1–14.

3.3.3. Indian Field Mouse (M. booduga). The highest poison consumption by the test animals could be observed for the bait prepared by using germinated finger millet (2.5 ± 0.3 g) and lowest for paddy (1.6 ± 0.2 g). The difference between the poison bait intake on first and second days was found to be statistically significant for paddy ($P < 0.01$) and pearl millet ($P < 0.05$). The maximum consumption of active ingredient (mg/kg^{-1}) in the test animals was 14.8±3.7 (paddy bait). Hundred percent mortality of *M. booduga* was observed on feeding with 0.005% concentration of bromadiolone bait prepared by using two germinated cereals, namely, paddy and finger millet. Mean days to death of experimental animals were 3.6 ± 1.5 (paddy) and 4.4 ± 3.9 (finger millet) (Table 3).

3.3.4. House Rat (R. rattus). It is apparent from the results that poison consumption by the test animals was found to be high for the bait prepared by using germinated paddy (11.4 ± 3.0 g) and less for finger millet (7.1 ± 1.0 g). The observed difference between the poison bait intake on first and second days was found to be statistically significant for all the three cereals. The ingestion of active ingredient (mg/kg^{-1}) in the test animals was found to be high in paddy bait (8.1 ± 3.2). However, cent percent mortality of *R. rattus* was not observed on feeding with 0.005% concentration of bromadiolone bait prepared by using germinated paddy. The baits prepared by using germinated cereals such as pearl millet and finger millet yielded hundred percent mortality. Days to death of experimental animals ranged between 3 and 14 (paddy, pearl millet, and finger millet) (Table 3).

In the no-choice tests, cent percent mortality of rodents could be observed in *B. bengalensis* (fed with bromadiolone in all germinated cereals bait), *M. meltada* (fed with bromadiolone in all germinated finger millet bait), *M. booduga* (fed with bromadiolone in germinated paddy and finger millet bait), and *R. rattus* (fed with bromadiolone in germinated pearl millet and finger millet bait) (Table 3).

3.4. Chronic Toxicity Tests: Choice Tests. The results of chronic toxicity studies on two-day exposure of 0.005% bromadiolone mixed with different geminated cereals (paddy, pearl millet, and finger millet) against the four species rodents under choice tests are presented in Table 4.

3.4.1. Lesser Bandicoot Rat (B. bengalensis). The experimental animals were found to feed more quantity of poison bait than the plain bait and the difference between them was found to be statistically significant ($P < 0.05$; 0.01; 0.001). The intake of active ingredient (mg/kg^{-1}) in the dead rodents ranged from 1.0 to 5.8 and in the survived animals from 0.7 to 1.8 in all the three cereals used in the bait. A maximum of ninety percent mortality of test animals could be observed only with the animals fed on the bait prepared by using pearl millet and finger millet. Days to death of experimental animals ranged between 1 and 11 (Table 4).

3.4.2. Soft Furred Field Rat (M. meltada). The experimental animals were found to feed significantly more quantity of poison bait prepared in germinated finger millet than the plain bait ($P < 0.05$) on both days of feeding. The intake of active ingredient (mg/kg^{-1}) ranged from 0.8 to 8.5 in the dead rodents in all the three cereals used in the bait. Cent percent mortality of test animals could be observed only with the animals fed on the bait prepared by using pearl millet. Days to death of experimental animals ranged between 2 and 14 (Table 4).

3.4.3. Indian Field Mouse (M. booduga). Insignificant difference was observed between the consumption of poison prepared in all the cereals and plain bait ($P > 0.05$) excepting germinated paddy bait consumption ($P < 0.01$). The intake of active ingredient (mg/kg^{-1}) ranged from 0.4 to 17.8 in the dead animals in all the three cereals used in the bait. The observed mortality was 80% for paddy and 70% each for pearl millet and finger millet. Days to death of experimental animals ranged between 3 and 10 (paddy), 3 and 7 (pearl millet), and 1 and 11 (finger millet) (Table 4).

3.4.4. House Rat (R. rattus). Definite trend could not be seen in the poison and plain bait consumption by the test animals and the difference between them was found to be statistically not significant ($P > 0.05$). The intake of active ingredient (mg/kg^{-1}) in the dead animals ranged from 1.9 to 8.6 in all the three cereals used in the bait. The pearl millet and finger millet bait produced a maximum of 90% mortality among the house rats. The paddy bait resulted in sixty percent mortality of test animals. Days to death of experimental animals ranged between 2 and 14.

The results of the toxicity studies of zinc phosphide and bromadiolone mixed with germinated cereals against four species were highly susceptible. The oral LD_{50} of Zn_3P_2 for rodents is usually 40 $mg\,kg^{-1}$ or less. Zn_3P_2 is a broad-spectrum toxin; there are some differences in the susceptibility of animal species [30]. The onset of poisoning is rapid following ingestion of Zn_3P_2 and usually occurs within 15 min to 4 h after ingestion of a toxic amount. Death from large doses usually occurs between 3 and 5 h [31]. The results of the present study also corroborate these earlier

TABLE 4: Mortality of four species of rodents after being fed on 0.005% bromadiolone baits of germinated cereals for two days in choice tests.

Species	Bait	Body weight (g) mean ± SD[a]	2-day poison consumption (g) mean ± SD[a]		P value[b]	Intake of active ingredient (mg/kg^{-1}) mean ± SD[a]		Mortality	Days to death mean ± SD[a]
			Poison	Plain		Dead animals	Survived animals		
B. bengalensis	Paddy	109.8 ± 16.3 (86–135)	8.3 ± 3.8 (3.1–13.5)	3.5 ± 1.7 (1–6.3)	0.005**	3.6 ± 1.5 (1.7–5.8)	1.8 ± 0.05 (0.7–1.8)	8/10	3.9 ± 2.3 (3–7)
	Pearl millet	104 ± 17.7 (80–130)	8.4 ± 2.1 (3–10)	4.9 ± 1.0 (3.5–6.8)	0.001***	3.8 ± 1.1 (1.5–5.2)	1.5	9/10	3.9 ± 3.1 (1–8)
	Finger millet	109.4 ± 25.3 (75–160)	6.4 ± 2.0 (1.3–4.2)	4.6 ± 0.8 (3.6–5.5)	0.016*	2.9 ± 0.9 (1.0–4.2)	1.0	9/10	4.3 ± 2.9 (3–11)
M. meltada	Paddy	44.2 ± 4.0 (39–50)	2.1 ± 1.5 (0.2–5)	5.3 ± 2.6 (1–8.9)	0.020*	2.3 ± 1.6 (0.8–5.5)	1.2 ± 0.9 (0.3–2.4)	6/10	4.0 ± 3.6 (4–8)
	Pearl millet	39.3 ± 3.1 (33–43)	3.1 ± 1.4 (0.5–5)	3.2 ± 1.9 (1–5.5)	0.852[NS]	4.0 ± 1.8 (0.9–5)	—	10/10	7.9 ± 3.7 (2–14)
	Finger millet	40.4 ± 5.4 (33–51)	5.2 ± 1.3 (3.2–7)	1.9 ± 2.4 (0–7)	0.021*	6.5 ± 1.7 (0.8–8.5)	1.7	9/10	6.2 ± 2.9 (4–10)
M. booduga	Paddy	8.6 ± 1.3 (6.95–11)	2.3 ± 0.5 (1.8–3.2)	1.0 ± 0.7 (0.1–2.1)	0.006**	12.6 ± 3.4 (7.7–17.8)	10.4 ± 1.1 (2–11.5)	8/10	4.9 ± 3.4 (3–10)
	Pearl millet	9.4 ± 0.9 (8.1–11)	1.5 ± 0.6 (0.7–2.7)	1.6 ± 0.6 (0.6–2.5)	0.531[NS]	8.4 ± 4.1 (3.4–16.0)	3.6 ± 0.1 (3.4–3.8)	7/10	3.4 ± 2.7 (3–7)
	Finger millet	8.5 ± 0.5 (7.8–9.1)	1.2 ± 0.5 (0.4–2.4)	1.4 ± 0.7 (0.5–2.9)	0.588[NS]	7.5 ± 3.6 (1.5–14.7)	2.7 ± 2.8 (0.4–7.2)	7/10	4.1 ± 4.9 (1–11)
R. rattus	Paddy	101.8 ± 22.4 (70–126)	7.6 ± 3.2 (3.8–13.6)	10.7 ± 3.5 (4.8–14.5)	0.126[NS]	3.9 ± 1.5 (1.9–6.8)	2.8 ± 0.5 (2.3–3.5)	6/10	2.5 ± 2.9 (2–9)
	Pearl millet	96.5 ± 17.4 (68–115)	8.2 ± 1.8 (5.8–12)	9.8 ± 2.2 (5.6–13.1)	0.218[NS]	4.5 ± 1.9 (2.9–8.6)	2.6	9/10	5.4 ± 2.7 (3–10)
	Finger millet	90.1 ± 11.3 (75–103)	8.1 ± 1.5 (4.5–10)	6.3 ± 1.0 (4.9–7.8)	0.031[NS]	4.6 ± 1.2 (2.9–6.8)	2.5	9/10	7.5 ± 4.1 (5–14)

[a] Mean and standard deviation values were obtained from observation of ten animals in each test (numbers in brackets are the range of values).
[b] The difference between poison and plain bait intake is statistically significant based on paired "t" test. $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; $^{NS}P > 0.05$.

observations and the mortality of the test animals started from 3 hrs onwards and it might be due to high quantity of consumption of poison in the bait. Parshad et al. [32] reported that, in the assessment of brodifacoum poison bait palatability in choice feeding test, rodent species (namely, *M. meltada*, *T. indica,* and *B. bengalensis*) consumed significantly less poison bait than the plain bait alternative. Similar results have been reported for *Mus musculus* [33], *T. indica,* and *M. hurrianae* [34]. The results of the present study corroborate these earlier results. Though more consumption was observed in paddy bait, the toxic consumption was comparatively less because some amount of chemicals was removed along with outer husk while eating. Similar trend has been observed by Chaudhary and Tripathi [35] with various species of rodents with difethialone (0.0025%) treated with pearl millet bait. A good-quality cereal is normally, on its own, sufficiently attractive to rodents to produce excellent results when used with an effective rodenticide. However, various attractants are sometimes added to bait [36]. Certain edible oils are known, however, to enhance bait uptake by rodents and for this reason one of them, corn (maize) oil, is component in a challenge diet advocated by the US Environmental Protection Agency (EPA) and frequently used in palatability testing. Cereal grains, either whole, broken rolled, or ground, produce satisfactory rodenticide baits and are widely used by both large manufacturers and small-scale formulators [37]. Besides these, the chosen three germinated cereals in the present study proved themselves that they are also capable of acting as suitable bait base for both selected rodenticides in bringing maximum mortality among the tested rodent pests under both no-choice and bi-choice tests in laboratory situations. The palatability of rodenticide bait to rodent species was found to be influenced by age/sex [38], quality of bait [3, 39–41], and concentration of rodenticides [42]. According to Krishnakumari [43], less nourishing foods are accepted if they are "tasty" with flavours or soft texture. Food selection in rats is determined by factors such as texture, odour, and taste cues [44, 45]. In the present study the germinated grains would have provided soft texture and palatability and hence the rodents might have preferred them.

4. Conclusions

The results suggests that the poison baits in the germinated cereals induced all the chosen four species of rodent pests to consume greater quantities of bait perhaps due to the bait carrier's palatability and texture. Therefore, these three germinated cereals may be recommended as a bait carrier for both zinc phosphide (2%) and bromadiolone (0.005%) poisons for the control of all these four species of rodent pests under field conditions. However, this requires field based trials with these rodenticides for making a final recommendation.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

The authors are thankful to UGC for granting financial assistance in the form of Rajiv Gandhi National Fellowship (Vide no. F.16-322/2006 (SA-II) dated 29 March 2007) to carry out this research work. The authors are thankful to The Management and Principal of Nehru Memorial College (Autonomous) for having rendered necessary facilities. The first author extends his gratitude to Bharathidasan University, Tiruchirappalli, to give necessary permission to publish this paper which was from a part of his Ph.D. thesis.

References

[1] M. S. Pradhan and S. S. Talmale, *A Checklist of Valid Indian Rodent Taxa (Mamalia: Rodentia)*, Zoological Survey of India, Kolkata, India, 2009.

[2] C. S. Malhi and C. Sheikher, "Some social and ecological consideration for rodent control in District Pauri of Garhwal Himalayas," *Tropical Pest Management*, vol. 35, no. 1, pp. 67–69, 1989.

[3] C. Sivaprakasam and G. Durairaj, "Burrow ecology of four ricefield rodents of Tamil Nadu, India," *International Journal of Ecology & Environmental Sciences*, vol. 21, no. 3, pp. 231–239, 1995.

[4] P. Neelanarayanan, R. Nagarajan, and R. Kanakasabai, "Burrow morphology of field rodents," *Journal of Bombay Natural History and Society*, vol. 93, no. 2, pp. 238–241, 1996.

[5] P. Neelanarayanan, *Predatory pressure of barn owl (Tyto alba stertens Hartert , 1929) on rodent pests—a field evaluation [Ph.D. thesis]*, Bharathidasan University, Tiruchirappalli, India, 1997.

[6] P. Neelanarayanan, "Magnitude of pre-harvest losses due to rodents in paddy, pulses, sugarcane and cotton crops in a portion of Cauvery delta, India," *Asian Journal of Animal Sciences*, vol. 3, no. 1, pp. 1–7, 2008.

[7] P. Neelanarayanan, "Population dynamics of Barn owl (*Tyto alba stertens* Hartert, 1929) in a portion of Cauvery delta, India," *Asian Journal of Animal Sciences*, vol. 3, no. 2, pp. 156–162, 2008.

[8] P. Neelanarayanan, R. Kanakasabai, and R. Nagarajan, "Rodent damage in Paddy in Tamil Nadu," *Rodent Newsletter*, vol. 17, no. 1-2, p. 6, 1993.

[9] P. Neelanarayanan, R. Kanakasabai, and R. Nagarajan, "An assessment of rodent damage to Pulse crop in Cauvery delta," *Rodent Newsletter*, vol. 17, no. 3-4, pp. 5–6, 1993.

[10] P. Neelanarayanan, R. Nagarajan, and R. Kanakasabai, "Method for population estimation of *Bandicota bengalensis* and *Mus booduga*," *Journal of Ecotoxicologyy and Environmental Monitoring*, vol. 5, no. 4, pp. 269–270, 1995.

[11] P. Neelanarayanan, R. Nagarajan, and R. Kanakasabai, "Evaluation of Zinc phosphide with prebaiting techniques in paddy fields," *Pestology*, vol. 19, no. 1, pp. 22–24, 1995.

[12] G. Calderón, N. Pini, J. Bolpe et al., "Hantavirus reservoir hosts associated with peridomestic habitats in Argentina," *Emerging Infectious Diseases*, vol. 5, no. 6, pp. 792–797, 1999.

[13] C. Castillo H, L. Sanhueza H, M. Täger F, S. Muñoz, G. Ossa A, and P. Vial C, "Seroprevalence of antibodies against hantavirus in 10 communities of the IX Region of Chile where hantavirus cardiopulmonary syndrome cases were reported," *Revista Medica de Chile*, vol. 130, no. 3, pp. 251–258, 2002.

[14] N. B. Vanasco, M. D. Sequeira, G. Sequeira, and H. D. Tarabla, "Associations between leptospiral infection and seropositivity

in rodents and environmental characteristics in Argentina," *Preventive Veterinary Medicine*, vol. 60, no. 3, pp. 227–235, 2003.

[15] A. P. Meehan, *Rats and Mice. Their Biology and Control*, The Rentokil Library, East Grinstead, UK, 1984.

[16] R. Pollitzer, *Plague*, vol. 22 of *Monograph*, World Health Organisation, Geneva, Switzerland, 1954.

[17] A. J. Carlson and F. Hoelzel, "Influence of texture of food on its acceptance by rats," *Science*, vol. 109, no. 2821, pp. 63–64, 1949.

[18] S. Sridhara, "Management of rodent pests-biological and behavioural aspects," *Indian Review of Life Sciences*, vol. 5, pp. 107–139, 1985.

[19] I. Prakash and R. P. Mathur, *Management of Rodent Pests*, Indian Council of Agricultural Research, New Delhi, India, 1987.

[20] S. R. Belmain, A. N. Meyer, R. Timbrine, and L. Penicela, "Managing rodent pests in households and food stores through intensive trapping," in *Rats, Mice and People: Rodent Biology and Management*, G. R. Singleton, L. A. Hinds, C. J. Krebs, and D. M. Spratt, Eds., ACIAR Monograph no. 96, pp. 440–445, 2002.

[21] G. Sasikala, P. Neelanarayanan, and C. Sivaprakasam, "Efficacy of three types of rodent traps in residential premises in Velayapatti Village, Tiruchirappalli District, Tamil Nadu," *Pestology*, vol. 32, no. 6, pp. 45–48, 2008.

[22] K. Srihari, S. Sridhara, and P. E. Cowan, "Toxicity of zinc phosphide to *Bandicota bengalensis*," *Mysore Journal of Agricultural Sciences*, vol. 13, pp. 57–59, 1979.

[23] P. Neelanarayanan and R. Kanakasabai, "Laboratory evaluation of Zinc phosphide and its impact on the Biochemistry of the soft furred field rat, *Millardia meltada* (Gray)," *Journal of Ecotoxicology and Environmental Monitoring*, vol. 2, no. 4, pp. 273–277, 1992.

[24] I. Prakash, *Rodent Pest Management: Principles and Practices*, vol. 4 of *Monograph*, Central Arid Zone Research Institute, 1976.

[25] P. Sakthivel, *Determination of effective poison bait carrier for rodent pests under laboratory and field conditions [Ph.D. thesis]*, Bharathidasan University, Tiruchirappalli, India, 2011.

[26] P. Sakthivel and P. Neelanarayanan, "Laboratory evaluation of germinated and non-germinated bait base for the management of the house rat, *Rattus rattus*," *African Zoology*, vol. 46, no. 2, pp. 406–412, 2011.

[27] P. Sakthivel, P. Neelanarayanan, and A. M. K. Mohan Rao, "Laboratory evaluation of germinated and non-germinated grains as rodenticide bait-base for control of three rodent pest species in Cauvery Delta, Tamil Nadu, India," *Pestology*, vol. 35, no. 8, pp. 36–44, 2011.

[28] J. Baskaran, R. Kanakasabai, and P. Neelanarayanan, "Laboratory evaluation of bromadiolone (0.005%) against the Indian soft furred field rat," *Millardia Meltada, (Gray). Pestology*, vol. 17, no. 2, pp. 29–35, 1993.

[29] A. Rajathi and P. Chandran, *SPSS for You*, MJP Publishers, Chennai, India, 2010.

[30] C. Eason, J. Ross, H. Blackie, and A. Fairweather, "Toxicology and ecotoxicology of zinc phosphide as used for pest control in New Zealand," *New Zealand Journal of Ecology*, vol. 37, no. 1, 2013.

[31] K. Parton, A. N. Bruère, and J. P. Chambers, *Veterinary Clinical Toxicology*, vol. 249 of *Vet Learn*, Massey University, Palmerston North, New Zealand, 3rd edition, 2006.

[32] V. R. Parshad, N. Ahmad, and G. Chopra, "Laboratory and field evaluation of brodifacoum for rodent control," *International Biodeterioration and Biodegradation*, vol. 21, pp. 107–112, 1985.

[33] R. Redfern, J. E. Gill, and M. R. Hadler, "Laboratory evaluation of WBA 8119 as a rodenticide for use against warfarin resistant and non resistant rats and mice," *Journal of Hygiene*, vol. 77, no. 3, pp. 419–426, 1976.

[34] R. P. Mathur and I. Prakash, "Evaluation of brodifacoum against the *Tatera indica*, *M. hurrianae* and *R. rattus*," *Journal of Hygiene*, vol. 87, no. 2, pp. 179–184, 1981.

[35] V. Chaudhary and R. S. Tripathi, "Evaluation of single dose efficacy of difethialone—a second-generation anticoagulant for the control of rodents inhabiting arid ecosystem," *Indian Journal of Agricultural Sciences*, vol. 76, no. 12, pp. 736–739, 2006.

[36] R. E. Marsh, "Bait additives as a means of improving acceptance by rodents," *EPPO Bulletin*, vol. 18, pp. 195–202, 1988.

[37] A. P. Buckle, "Rodent control methods: chemical," in *Rodent Pests and Their Control*, A. P. Buckle and R. H. Smith, Eds., pp. 127–160, CAB International, Wallingford, UK, 1994.

[38] C. Sivaprakasam and G. Durairaj, "Laboratory evaluation of bromadiolone for the control of *Millardia meltada* and *Mus booduga*," *Bulletin of Grain Technology*, vol. 30, no. 1, pp. 63–67, 1992.

[39] M. Lund and J. Lodal, "Palatability testing," Annual Report (1983-84), Danish Pest Infestation Laboratory, 1985.

[40] M. Lund, "Selection of baits and their distribution," in *Rodent Pest Management*, I. Prakash, Ed., pp. 261–267, CRC Press, Boca Raton, Fla, USA, 1988.

[41] M. M. Safi, A. Pervez, S. Ahmad, and S. M. Ahmed, "Some approaches to enhancing poison bait acceptance in the lesser bandicoot rat, *Bandicota bengalensis*," *Tropical Science*, vol. 33, pp. 350–358, 1993.

[42] B. K. Soni and I. Prakash, "Efficacy of brodifacoum against the house mouse," *Pesticides*, vol. 18, pp. 15–17, 1984.

[43] M. K. Krishnakumari, *Studies on the rodenticide and rodent repellents with special reference to the control of the black rat R. rattus L.) [Ph.D. thesis]*, University of Mysore, Mysore, India, 1968.

[44] W. B. Jackson, "Feeding patterns in domestic rodents," *Pest Control*, vol. 33, no. 8, pp. 12–15, 1965.

[45] R. W. Bullard and S. A. Shumake, "Food base flavour additive improves bait acceptance by rice field rats," *Journal of Wildlife Management*, vol. 41, no. 2, pp. 290–297, 1977.