II. MATERIALS AND METHODS

2.1. Laboratory Evaluation:

The following tests *viz.*., two choice, multiple choice and toxicity (acute and chronic) tests were conducted in the laboratory conditions for the present study.

2.1.1. The Experimental Animals:

i. The Lesser Bandicoot Rat, (*Bandicota bengalensis* Gray, 1835)

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<td><em>Bandicota</em></td>
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There are three recognized sub species of *B. bengalensis* in India namely, *B. bengalensis bengalensis* (Gray), *B. bengalensis varius* (Thomus) and *B. bengalensis wardi* (Wroughton). It is also called as the “Indian mole rat”.

The lesser bandicoot is robust with a round head and a broad muzzle. The body is covered with coarse fur which forms black-tipped piles on the dorsal side. The colour on the dorsal side is dark brown but may be blackish, pale brown or reddish. Feet are dark but digits
are paler. Tail is completely dark and paler below occasionally. The colour of the belly is grey or light grey and rarely whitish.

**Distribution:** Except the extremes of Western Thar Desert, *B. bengalensis* is widely distributed throughout India, Pakistan, Nepal, Bhutan, Bangladesh, Srilanka and South East Asia. In recent years it is being reported from urban areas of Jodhpur and Bikaner city.

**Habitat and Habits:** The lesser bandicoot rat is well adapted to various habitats and lives in different ecological conditions which include cultivated fields, pastures, forests, mountains, inter-tidal mangrove zones, semi arid zones and of late as a commensal in towns and cities across India. However, basically it requires damp soil for burrowing.

It is completely a fossorial rodent which favours embankments around paddy fields. The burrows are elaborate with several openings. The entrance is characteristically covered with a heap of dug out soil, which are usually small lumps of soil or large sized pebbles (Neelanarayanan *et al.*, 1996). Burrow opening lead to branching and winding tunnels, which are interconnected. Several tunnels expand to serve as brood/nesting chambers. Some others are utilized as storage chambers. The numbers of burrow openings vary from 1 to 16. Burrow depth ranges from 30cm to 100cm and length from 43cm to 450cm. Burrows are dug in crop fields, parks and near garbage dumping yards *etc.*, In godowns burrows are dug even in cemented floor and walls. Considerable amount of grain is hoarded inside the burrows. The rat is nocturnal. Although reported to be colonial, during breeding season males and females with her young seem to live in separate burrows.

**Breeding:** The mole rat breeds throughout the year. Definite peaks occur during different seasons across the country. In Karnataka breeding lasts from early July to end of April with a
peak reproductive period seen during September to October. The annual calculated reproductive rate was 67 young/female/year (Srihari and Govind Raj, 1984). In Cauvery delta, Tamil Nadu, breeding activity of *B. bengalensis* was observed, during January, February, July, August and October. Although, the breeding activity of *B. bengalensis* was observed in the months of July, August and October, most of the population bred only during January and February during the study period (1993-1994). The high reproductive activity of rodent pests is due to the ripening and harvesting stages of the *Samba* and *Thaladi* seasons paddy crop during this period and when the climatic conditions are conducive and availability of food is abundant (Neelanarayanan *et al.*, 1995).

**Food:** *B. bengalensis* is omnivorous with a definite preference towards food grains. When vegetative food is not available it easily switches over to insects, molluscs etc. thus exhibiting seasonal adaptation to food and a capacity to select the best balanced diet depending on availability.

**Pest status:** The lesser bandicoot is a serious pest of agriculture in India causing extensive damage to paddy, wheat, maize, sorghum, ragi, sugarcane, groundnut, pea, many vegetables and coconut nurseries. Their burrows were also reported from tapioca, colocasia, yam and rubber plantations of Kerala. The burrowing activity of lesser bandicoot rats cause damage to roots causing the slow death of trees/plants in many orchards, plantations and perennial crops like mulberry, apple *etc*. Similarly their burrowing activity interferes with irrigation of marshy crops such as paddy and leads to indirect losses (Sridhara and Tripathi, 2005; Rao 2010).
ii. Soft furred field rat (*Millardia meltada* Gray, 1835)

- **Phylum:** Chordata
- **Subphylum:** Vertebrata
- **Class:** Mammalia
- **Order:** Rodentia
- **Family:** Muridae
- **Subfamily:** Murinae
- **Genus:** Millardia
- **Species:** *meltada*

The metabol, *Millardia meltada* has very soft fur on the body. The body colour is light to dark grey above and pale below.

**Distribution:** It is widely distributed throughout India except the north-east mountainous regions.

**Habitat:** It is one of the most predominant rodent pests in almost all the states, inhabiting crop fields usually choosing the drier patches. It is also reported from the ruderal habitats, scrub grassland, gravely areas and sandy plains of Rajasthan.

**Habits:** Nocturnal. It occupies the cracks and crevices in the dried up crop fields after harvest as well as the deserted burrows of other rodents. Also it digs simple and shallow burrows.

**Breeding:** In Karnataka the breeding season of *M. meltada* extended from July to early March with peak reproduction during September-November. The annual productivity was 53young/females/breeding season. (Govind Raj and Srihari, 1989). In Rajasthan, metads bred throughout the year with peak reproduction occurring in March-October (Rana and Prakash,
In Cauvery delta, Tamil Nadu, *M. meltada* populations were found to breed during January and February during the study period (1993 to 1995) (Neelanarayanan *et al*., 1995).

**Pest status:** *M. meltada* is a serious pest of kharif crops like ragi, jowar, maize, ground nut cotton, til, and moong. During rabi they inflict damage to wheat, barley and brown sarson. They are also reported to cause damage to natural grass lands and fodder crops in Rajasthan (Sridhara and Tripathi, 2005; Rao 2010).

### iii. The Indian field mouse (*Mus booduga* Gray, 1837)

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Dorsal fur varies in colour from pale sandy in the desert regions to dark brown to greyish in most regions of India. Ventrum is white.

**Distribution:** Throughout India.

**Habitat and Habits:** *M. booduga* is found in crop fields especially in irrigated ones. It is fossorial and nocturnal. Burrows have 2-4 surface openings with a depth of 50–60 cm and length ranges from 45 to 65 cm. The burrows have 1-2 nesting chambers and have smaller openings compared to other species. The 1 cm opening is characterised by scooped soil at the entrance with small pebbles (Neelanarayanan *et al*., 1996). Hoarding of grains up to 7g per burrow is reported.
Breeding: Breeds throughout the year in Punjab, except during very cold months. In South India breeding occurred throughout the year with low reproductive activity during March to July. Annual productivity was 21 young/female/year (Chandrahas, 1974; Rao, 1977). However later studies revealed that the breeding period from July to March with a peak in September to October and annual productivity as 52/female/year in Karnataka (Sridhara, 1999).

Pest status: Pest of rice, wheat, groundnut, raddish crops etc (Sridhara and Tripathi, 2005; Rao 2010).

iv. The house rat (*Rattus rattus* Linnaeus, 1758)

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*R. rattus* is also called roof rat, black rat and ship rat. It is the most abundant and widely distributed rodent species in India as well as in the world. Biswas and Tiwari (1969) recognized at least 14 subspecies within our country. It is characterized by long tail, slender body and pointed snout as well as the belly. The dorsal fur is mostly blackish in commensal forms which range to yellow to brown black with pale white belly in wide forms.

Distribution: All over the world.
**Habitat:** Mostly commensal living in houses, godowns, stores, poultry farms, crop fields adjacent to villages, plantation crops especially coconut, open country, forests and in the hills.

**Habits:** It is nocturnal and colonial.

**Breeding:** House rats breed throughout the year, reportedly with two peaks of reproduction *viz.*, March to April and August to September (Krishnakumari *et al.*, 1992). Breeding was also reported from March to December with a peak in September to November. The annual productivity was 70/female/year (Krishnamurthy, 1990) (Sridhara and Tripathi, 2005; Rao 2010).

### 2.1.2. Procurement of Test Animals

Three species of field rodent pests *viz.*, *Bandicota bengalensis*, *Millardia meltada* and *Mus booduga* which are found in the crops fields of Cauvery delta, South India, and one species of commensal rodent, *Rattus 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 (1988). They were brought to the laboratory, weighed, sexed and lodged in individual cages (60 cm x 30 cm x 30 cm) placed in the live animal keeping rooms of the Rodent Laboratory, Nehru Memorial 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 by using wooden Sherman live traps and wonder traps. These traps (were baited with any one of the materials such as pieces of dried fish, tomato and pieces of coconut) were set in the evening and placed
on the runways of rats (Belmain et al., 2002). In order to avoid trap shyness for wooden Sherman traps, the traps were set in “off” position for first two days with chosen baits and on third day onwards they were set in “on” position (Sasikala et al., 2008). In the next day morning between morning 6 and 7 a.m., the traps were checked and the trapped rodents were brought to the laboratory weighed, sexed and lodged in the rodent cages.

2.1.3. 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 non-germinated paddy and water was provided to them. For each set of experiments ten healthy animals (5 males + 5 females), individually, were used.

2.1.4. Selection of grains

The following cereals: paddy (Oryza sativa Linnaeus), pearl millet (Pennisetum typhoides Staph and Hubbard) and ragi (Eleusine coracana Gaertn); and pulses: green gram (Phaseolus aureus Roeeh), black gram (Phaseolus mungo Linnaeus) and bengal gram (Cicer arietinum Linnaeus) were selected for the present study and tested in two forms viz., germinated and non-germinated.

2.1.5. The germination process

The selected cereals and pulses were soaked individually overnight in water. Later, the water was drained carefully and the grains were transferred on a clean wet cotton clothe and gently tied. This was kept at room temperature until the grains germinated.
2.2. Design of the laboratory Experiments

2.2.1. Feeding trails:

The feeding tests of the present study were done by following the methods adopted by Vanitha et al., (1997), Kaur and Parshad (2002). Two choice tests, multiple choice tests and toxicity tests were carried out from April 2006 to December 2007.

2.2.2. Two - choice tests- (Germinated grains versus Non-germinated grains)

The individually caged each animal was offered with 20g of each selected germinated and non-germinated cereals and pulses in separate stainless steel cups.

One set of animals comprising of 10 animals each with five males and five females were used individually, for each grain’s two-choice tests, multiple-choice tests and toxicity tests. For, instance, one set of animals used for paddy two-choice tests were not used for testing any other grains’ preference under two-choice, multiple choice and toxicity tests (Zinc phosphide and Bromadiolone).

2.2.3. Multiple-choice Tests (Germinated grains only)

The individually caged rats were offered with 20g each of the selected six germinated grains (3 cereals and 3 pulses) in six individual containers.

The position of each grain (in both forms i.e., germinated and non-germinated in two-choice tests; germinated grains in multiple choice tests) in the cup was changed every day in order to (avoid place preference trend) get the unbiased food preference by the experimental animals.
Both two-choice and multiple-choice tests were conducted for five consecutive days. The quantity of daily food consumption by caged rodents were weighed and recorded for each form (germinated and non-germinated). An electronic balance with an accuracy of 0.05g was used for weighing the grains after every 24 hrs. Each cup was replenished with fresh grains in the respective forms and 20 g quantity once in 24 hrs. The amount of actual food consumed by the test animals were transformed into g/100 g body weight. Water was provided to the animals ad libitum during all these tests.

2.3. Toxicity tests

Zinc phosphide and Bramadiolone (0.005%) were chosen for the present study to evaluate their efficacy by using germinated cereals as poison bait carrier against rodents under laboratory conditions.

2.3.1. Acute Rodenticide: Zinc phosphide

Zinc phosphide (Zn$_3$P$_2$) is one the most commonly used acute rodenticides and is the only one widely available for unrestricted use by non-professionals. It is generally available as a grey or black powder of 80-95% purity, having a strong garlic odour and is toxic to a wide range of rodent pests. Zinc phosphide is applied in baits at concentrations ranging from 1 to 5% although 2% is most widely used. Ready-for-use formulations are also available, particularly in the USA (Buckle, 1994).

The mode of action of zinc phosphide is by the release of phosphine gas in the acid environment of the stomach, the gas entering the bloodstream causing heart failure and damage to internal organs. There is no specific antidote available and the compound is toxic to other
vertebrates as well. The LD$_{50}$ values of this rodenticide for pig, dog, cat, chicken, and duck are in the range 20-40 mg kg$^{-1}$ (Buckle, 1994).

2.3.2. Anticoagulants: Chronic rodenticide: Bromadiolone (0.005%)

The discovery of the anticoagulant rodenticides was, without doubt, the most important step ever made towards safer and more effective rodent control.

Bromadiolone, 3-[3-(4'-bromobiphenyl-4-yl) - 3-hydroxy-1-phenylpropyl] - 4-hydroxycoumarin [28772-56-7], C$_{30}$H$_{23}$BrO$_4$, was patented in 1968 and introduced to the market as a rodenticide in 1976.

The second generation anticoagulants, such as brodifacoum and bromadiolone, are more toxic than first generation anticoagulant rodenticides (Eason and Wickstrom, 2001). Their superior potency, and their associated greater potential to affect wildlife compared to first generation anticoagulants, is related to their greater affinity for vitamin K-epoxide reductase, and subsequent accumulation and persistence in the liver and kidneys after absorption (Huckle et al. 1988; Parmar et al. 1987).

Bromadiolone is widely used to control rats and mice in commensal and agricultural situations. It has variety of formulations, including cereal-based baits, oil-based and powder concentrates, containing 0.1 - 0.5% of the active ingredient, and tracking dusts at 0.1 - 2.0% strength. They are sold under a number of trade names, including ‘Maki’, ‘Contrac’, ‘Super-Caid’ and ‘Bromone’ (Buckle, 1994).

In the present study acute toxicity studies were carried out with two different concentrations of zinc phosphide i.e., 2% for B. bengalensis (Srihari et al., 1979), 1.5% for M. meltada (Neelanarayanan and Kanakasabai, 1992) and M. booduga. However, Prakash (1976)
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 *viz.*, germinated paddy, pearl millet and ragi and because of their low cost and easy availability when compared to pulses were used as bait carrier for the chosen rodenticides. 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.* (1993).

The zinc phosphide manufactured by M/s. United Phosphorus Limited, Vapi, Gujarat and marketed by M/s. SWAL corporation Ltd., Mumbai, India were used. The bromadiolone, a single-dose anticoagulant available as 0.005% powder formulation produced and supplied by M/s. Pest Control (India) Pvt. Ltd., Chennai, Tamil Nadu was used. Both no-choice and choice test of zinc phosphide and bromadiolone was evaluated against four commonly available rodent species of our area *viz.*, *B. bengalensis*, *M. meltada*, *M. booduga* and *R. rattus*. Ten healthy animals were used, individually, during these toxicity studies.

### 2.3.3. Preparation of Poison baits

Poison bait at 1.5% and 2% zinc phosphide concentrations was prepared as follows:

- **1.5% poison bait:** 1.5 g zinc phosphide + 1.5 g coconut oil + 97 g of germinated cereals,
  Individually,

- **2% poison bait:** 2 g zinc phosphide + 2 g coconut oil + 96 g of germinated cereals, individually

Bromadiolone (0.005%) poison bait was prepared with the following ingredients:
2% poison bait: 2 g Bromadiolone (Powder formulation) + 2 g coconut oil + 96 g of germinated cereals, individually.

2.3.4. 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. Each caged rat was offered a cup of 20g poison bait and a cup of water. At the end of every 24 hours, poison bait consumption, mortality and hours to death (for Zn$_3$P$_2$)/ days to death (Bromadiolone) were recorded.

2.3.5. Choice tests

20g of poison prepared in the germinated cereals and 20g of plain bait (its counterpart in non-germinated 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 rats, 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 and 14 days for bromadiolone. At the end of every 24 hours, poison/plain bait consumption, were recorded.
2.4. Field Evaluation

2.4.1. Study area

The present work was carried out in Puthamampatti, Kottathur, and Mannachanallur areas belong to Tiruchirappalli District, Tamil Nadu, India (Fig. 1). The field evaluation works were carried out in the chosen crop fields between August 2007 and December 2010.

2.4.2. Temperature

The mean monthly maximum and minimum ambient temperature in the study area for the period from January 2007 to December 2010 ranged with a minimum of 15.0° C and a maximum of 40.2° C.

2.2.3. Rainfall

The chosen study area receives most of its precipitation during north- east monsoon which sets in October and ends in December every year. The observed annual mean monthly rainfall in the study area for the period from January 2007 to December 2010 fluctuated between 0 mm and 314.49 mm. The normal precipitation for a year in the Tiruchirappalli district is 823.5 mm per annum. During the present study period i.e., 2007, 2008, 2009 and 2010 the study area received annual rain fall of 751.07 mm, 1074.82 mm, 847.34 mm and 799.3 mm, respectively. This indicates that 2008 received a high precipitation followed 2009, 2010 and 2007 (Fig. 2)
Fig 2: The monthly rainfall (mm) at Tiruchirappall district during 2007 to 2010.

2.4.4. Cropping patterns

In the Cauvery delta of Tamil Nadu, crops like paddy (*Oryza sativa*), pulses (black gram, *Phaseolus mungo* and green gram, *Phaseolus aureas*), sugarcane (*Saccharum officinarum*), cotton (*Gossypium hirsutum*), groundnut (*Arachis hypogea*) and soybeans (*Glycine max*) are normally grown of which the paddy is the predominant crop.

In this area, the paddy crop is grown in three cropping seasons viz., *Kuruvai, Thaladi* and *Samba*. The *Kuruvai* is the first cropping season of short duration (105-110 days) and is grown between June and September. The *Thaladi* paddy crop is a follow up crop of *Kuruvai*, cultivated after ploughing and preparing the lands. The age of the *Thaladi* is 140 days and the cultivable period is September/October/January/February. *Samba* season paddy crop is a
single crop of long duration (165 days) and is sown in early August, transplanted in mid-
September and harvested in mid-January. The *Kuruvai* crop is grown by using ground water
while the *Thaladi* and *Samba* season paddy crops are cultivated by using *Cauvery* river water
and ground water as well. Of these three seasons paddy crop, *Samba* season paddy crop was
chosen as experimental fields for the present study.

Pulses (Green gram, Black gram), Groundnut and Sunflower crops are grown soon
after the harvest of paddy crop. Sugarcane crop is grown between February and December in
certain portions of the chosen study area. In a portion of paddy fallows, cotton crop is
cultivated from February to August.

### 2.4.5. Selection of Crop fields

Among the crops grown in the study area, the following four different crop fields *viz.*, paddy (*Samba* season), black gram, sunflower and cotton were chosen to evaluate the efficacy
of 2% zinc phosphide and bromadiolone (0.005%) baits mixed with germinated cereal (paddy)
against rodent pests. Besides this in *Samba* season paddy crop fields the chosen rodenticides
were also mixed with the other two germinated grains *viz.*, pearl millet and ragi and evaluated.

### 2.4.6. Selection of Study plots

In the chosen study area *i.e.*, near Mannachanallur, Tiruchirappalli district, 7 ha paddy
fields were selected. The distance between the two chosen paddy fields was maintained as
100m on all sides. Of the selected 7 ha paddy fields, three 1 ha size fields were used for 2%
zinc phosphide bait (prepared by using germinated paddy, pearl millet and ragi) were treated,
individually; and in another three 1 ha size fields the bromadiolone (0.005%) bait (prepared by
using germinated paddy, pearl millet and ragi) were used; and 1 ha field was maintained as control field (no-treatment) for comparison. This study was done in the Samba season crop fields cultivated during 2008, 2009 and 2010.

A total of 3 ha black gram plots were chosen in study area adjacent to Mannachanallur village, Tiruchirappalli district. Of these, 1 ha plot was used for zinc phosphide (2%) bait (germinated paddy was used as a bait material) application; and 1 ha for bromadiolone (0.005%) bait (germinated paddy was used as a bait material) use and the remaining 1 ha for control plot (no-treatment) for comparison. This study was carried out during 2008, 2009 and 2010.

In Kottathur village, Tiruchirappalli district a total of 3 ha sunflower plots were chosen. Of these, in 1 ha plot each zinc phosphide (2%) and bromadiolone (0.005%) bait (prepared in germinated paddy) was used; and the remaining 1 ha was maintained for control (no-treatment) for comparison. Evaluation of these two rodenticides were done with three replicates i.e., in the sunflower crops grown during 2008, 2009 and 2010.

In toto, 3 ha cotton crop fields were chosen for the present study near to Kottathur village, Tiruchirappalli district. Of them, 1 ha crop field for zinc phosphide (2%) (germinated paddy was used as a bait material) and 1 ha for bromadiolone (0.005%) (Germinated paddy was used as a bait material) and the remaining 1 ha for control plot (no-treatment) for comparison. Evaluation of efficacy of rodenticides was done with triplicates (i.e., the cotton crop cultivated during 2008, 2009 and 2010).

The data collected from these four crop fields for three consecutive years (2008, 2009 and 2010) were pooled and analysed, individually.
2.4.7. Estimation of rodent population: Live burrow count

In all the chosen crop fields the rodent population was estimated by live burrow count method as suggested by Neelanarayanan et al. (1995a) which is modified method of Barnett and Prakash (1975) and Prakash and Mathur (1987).

The burrow entrances of rodent pests in Cauvery delta, Tamil Nadu, are species specific (Sivaprakasam, 1988; Neelanarayanan et al., 1996). The burrow entrances of *B. bengalensis* have large quantities of heaped soil with large sized pebbles while the *M. booduga* burrow entrances have small quantity of heaped soil with small sized pebbles. Both the rodents plug their burrows entrances after entering into it. The burrow entrances of *M. meltada* do not have the heap of soil and the burrows go vertically downwards and remained open. The burrows of *T. indica* can be observed in the barren lands and often they have more than one opening with small quantity of heaped soil. The openings are adjacent to each other (Sivaprakasam, 1988; Neelanarayanan et al., 1996).

The population of *B. bengalensis* and *M. booduga* were estimated by directly enumerating the plugged burrow entrances (Neelanarayanan et al., 1995a). *M. meltada* population was estimated as follows; all the burrow openings unplugged seen in chosen crop fields were plugged with mud in the evening hours. The unplugged burrows were counted in the next morning. All the bunds of the selected crop fields (of 1 ha size) were observed for live or active burrows of rodent pests and they were enumerated and recorded. In the chosen developmental stages of the selected crops, the populations of the rodent pests were estimated.
before and after poison bait treatment in the experimental fields and reference/control plots as well. The data obtained from three replicates (2008, 2009 and 2010) were pooled into one observation. The population of rodent pests were given in number of live burrows/ha.

2.4.8. Measuring of rodenticide efficacy on mortality

The efficacy of rodenticides on the mortality of rodent pests was calculated by using the formula of Henderson and Tilton (1955) and adopted by Buckle et al., (1984), Ahmad and Parshad (1987), Sheikher and Jain (1991) and Jakel et al., (2006).

\[
\text{% of mortality} = 100 \left(1 - \frac{t_2 r_1}{t_1 r_2}\right)
\]

Where

\( t_1 \) = Pre treatment population of rodent pest in treated plot

\( t_2 \) = Post treatment population of rodent pest in treated plot

\( r_1 \) = Pre treatment population of rodent pest in reference plot

\( r_2 \) = Post treatment population of rodent pest in reference plot

2.4.9. Rodent damage assessment

In the present study, depredation by rodent pests was assessed in all the chosen crop fields and during two developmental stages of each crop during the study period.

2.4.10. Paddy

Diagonal method was adopted for the rodent depredation assessment in paddy crop fields as suggested by Posamentier (1989) and Kanakasabai et al. (1995). It was done during boot leaf and maturation stages of paddy crop in all the experimental and control plots.
In the selected study plots, a diagonal line was laid in which at every 3 m interval one sq ft (30 cm²) quadrats were laid. In each quadrat, the tillers present in hills were examined for damaged and undamaged and they were enumerated and percentage of tiller damage was then calculated as given below.

\[
\text{Percentage of damaged tillers} = \frac{\text{No. of tillers damaged}}{\text{Total No. of tillers examined}} \times 100
\]

Percentage of Rodent damage reduction in the rodenticide treated crop fields were compared to control fields and the same was calculated as suggested by (Shafi, 1991)

2.4.11. Black gram

The rodent pests’ damage in pod formation and pod maturation stages of black gram crop was assessed by following diagonal method adopted by Neelanarayanan et al. (1997). A diagonal line was laid in the selected crop fields and at every 5 m interval one sq ft (30 cm²) quadrats were chosen. In each quadrat, the cut (plant parts and pods) and uncut plants were enumerated and percentage of damage was calculated as described below.

\[
\text{Percentage of damaged plants/ pods} = \frac{\text{No. of plants with pods damage}}{\text{Total No. of plants examined}} \times 100
\]

2.4.12. Sunflower

The rodent pests’ damage in pod formation and pod maturation stages of sunflower crop was assessed by following quadrat method adopted by Sakthivel and Neelanarayanan
(2007). A total of nine quadrats, each with m² size were laid. The first set quadrats were placed
t at four corners of the plot and the next four quadrats were inner to the periphery of the
selected crop. The ninth was laid at the centre of the field. In each quadrat, the cut (plant parts
and pods) and uncut parts were enumerated and percentage of damage was calculated as
described below.

\[
\text{Percentage of damaged plants/pods} = \frac{\text{No. of plants with pods damage}}{\text{Total No. of plants examined}} \times 100
\]

2.4.13. Cotton

The damage caused by rodents in unripe boll stage and boll maturation stages of cotton
crop was assessed by row method as suggested by Neelanarayan et al. (1994). The total number
of rows in the selected study plots was enumerated and at every tenth row of the crop, randomly 20
plants were sampled for rodent depredation. Among them, the number of cut (parts of plants
including unripe and ripe bolls of cotton) and uncut cotton plants were counted for computation of
percent damage by the rodent pest as given below.

\[
\text{Percentage of damaged boll in cotton/ha} = \frac{\text{Number of plants damaged}}{\text{Total No. of plants examined}} \times 100
\]

Percentage of Rodent damage reduction in all crops the treated area compared to control area
was calculated as under (Safi, 1991)
\[
\text{\% of Damage reduction} = \frac{\text{\% of Damage in control} - \text{\% of Damage in treated}}{\text{\% of Damage in control}} \times 100
\]

The rodent depredation assessment was made in the rodenticides treated and control plots along with rodent population estimation. Rodent depredation assessment was made before and after the treatment of poison bait in the experimental and control plots as well.

### 2.4.14. Baiting method

Two days of pre-baiting with plain bait as suggested by Neelanarayanan et al. (1995a) was done in the selected crop fields. On the third day the prepared baits (2\% zinc phosphide) were placed in two places i.e., both at station (8 m interval) and active burrow entrances (10 g each) of experimental crop fields during evening hours of the day as suggested by Baskaran et al. (1995). The prepared baits (bromadiolone) were placed both at station (8 m interval) and active burrow entrances (20 g each) of experimental crop fields during evening hours of the day as suggested by Baskaran et al. (1995). No pre-baiting was done for bromadiolone treated crop fields.

In paddy crop fields, the rodenticidal baiting was done during the developmental stages like boot leaf and maturation stages. In Black gram crop fields rodenticidal baiting was done in pod formation and pod maturation stages. In Sunflower crop fields, the rodenticidal baiting was done only during Maturation stage. In Cotton crop fields, the rodenticidal baiting was done during unripe boll stage and second maturation stages.
2.5. Statistical analysis

All the data were analysed by using SPSS version 16.0 as described by Rajathi and Chandran, 2010.

**Independent \( t \) test:** To test the difference in grains consumption between germinated and non-germinated under two-choice tests. This test was subjected to find the difference between the population of rodents in pre and post treatment (rodenticides) crop fields. Further the same test was also used to find the difference between the percentage of damage in pre and post treatment (rodenticides) crop fields.

**Paired \( t \) test:** This test was used to find the difference between the consumption of poison and plain bait by the experimental animals under laboratory conditions.

**One Way and Two Way ANOVA:** The data on food consumption pertaining to four different species of rodents under multiple-choice tests were subjected to one way analysis of variance (ANOVA- Duncan's Multiple Range Test and Tukey Honesty Significant Difference (HSD) – was used to identify the difference among means of six germinated bait consumption). It was also adopted to find the difference between the crop yield of control and rodenticide treated fields.