ALL INDIA NETWORK PROJECT ON VERTEBRATE PEST MANAGEMENT

(RODENT CONTROL)

PROGRESS REPORT
2012-13 to 2014-2015

NETWORK COORDINATING UNIT
ALL INDIA NETWORK PROJECT ON VERTEBRATE PEST MANAGEMENT
ICAR-CENTRAL ARID ZONE RESEARCH INSTITUTE
JODHPUR-342 003

COORDINATOR'S REPORT

I am extremely happy to present the Progress Report of the Rodent control component of All India Network Project on Vertebrate Pest Management. This period has proved quite historic as the scope of the AINP was broadened by merging two AINPs, i.e., Rodent Control and Agricultural Ornithology, besides including a component of higher vertebrates in the ambit of new AINP on Vertebrate Pest Management from 2014-15. Besides the existing centers four new voluntary center centers viz., Bhubaneswar and Thrissur (for rodent control) and Trichy and Dapodi (for Agril. Ornithology) and six voluntary centers for higher vertebrates (three at Bangalore, one each at Hyderabad, Solan, Jodhpur and Delhi) were added.

I feel immense satisfaction that the project scientists have strived hard to achieve the mandates allotted to their centers during the Guwahati Meeting in 2013. The Project registered steady progress in identifying the rodent pest scenario in selected agro-ecological regions of the country, evaluation of newer strategies of rodent pest management and transfer of rodent management technologies.

Survey and surveillance activities undertaken in different agro-climatic regions revealed that lesser bandicoot rat, *Bandicota bengalensis* continued to be the number 1 rodent pest in most of the crops and cropping systems at national level. The species has shown its further spread in hot arid regions and Arunachal Pradesh and has established its populations in rice fields of Andaman & Nicobar Islands. And this a matter of great concern to us as the species is highly aggressive and colonial. Besides being highly destructive, it can replace the native rodents as we have observed in other areas. In hot arid regions, the two gerbils, *Tatera indica* and *Meriones hurrianae* maintained their predominance in rainfed as well as irrigated croplands.

In Northeastern, Southern dry and hilly zones of Karnataka besides the predominance of *B. bengalensis* other species reported were *T. indica, Milardia meltada, Mus playthrix and Mus booduga* in varying proportions. In the coastal zone of Karnataka, *Funambulus palmarum B. bengalensis, M. booduga* and *R. rattus* were the major problem species. However in the Krishna Zone (AP) only two species viz., *B. bengalensis* and *M. booduga* were reported from rice fields, but in Northern Telangana Zone *B. bengalensis, B. indica, R. rattus, M. booduga, M. musculus, M. meltada* and *T. indica* were reported. Though *B. bengalensis* was predominant in in rice-wheat-sugarcane cropping system and in rice-wheat-maize cropping system in Punjab, the second most prevalent species was *M. booduga* in wheat-sugarcane cropping system and *T. indica in* rice-wheat-maize cropping system. In the NEH region, *R. rattus, R. sikkimensis* and *B. bengalensis* were major problem species in rainfed crops in East Siang, West Siang, Lower Dibang valley and Lohit districts of Arunachal Pradesh whereas *B. bengalensis, B. indica, R. sikkimmensis, R. rattus, Mus musculus* and *Dremnomys lokriah* were reported from North Bank Plain Zone and Lower and Central Brahmaputra Valley Zone in Assam

In recent years, the project has reported rodent diversity in new areas like Andaman and Nicobar Islands where three new species viz., *Cremnomys cutchicus, M. booduga,* and *B. bengalensis* were reported. Likewise from cold arid regions of Leh Ladakh, four species were reported from crop fields, grasslands and stores & godowns situated at different altitudes. They were *Rattus turkastinicus, Pitymus lecurus, Marmota himalayana and M. booduga.* Of this occurrence of *M. booduga* was reported from the region first time. In the Kargil areas crop fields were observed to be infested with mole rats (either *B. bengalensis or Nesokia indica*).

If we see the extent of damage to various crops, Sugarcane and groundnut reported as high as 14 and 29 % damage by rodents in Assam and AP, respectively, whereas ground nut crop registered 12-17% damage in western Rajasthan. Maize and sorghum in southern transitional zone of Karnataka recorded 3.2- 3.8% plant damage by rodents. In Punjab, with a tiller damage of about 2%, rice suffered a yield loss of 15-90 kg/ha due to rodent infestation in the less irrigated zone of the State. In Karnataka, Andhra Pradesh, Assam, Arunachal Pradesh and Andaman and Nicobar islands this crop registered up to 7.2, 12.3, 10.3, 2.2 and 22% percent tiller damage respectively. Wheat and cumin recorded 16.2 and 7.56% damage due to rodents in Narmada canal areas of western Rajasthan. Pulses, like cowpea, mung, bengal gram, pea, soybean etc registered 4-9% damage in different regions. Vegetable crops suffered rodent depredation of 4-13% in NEH region.

Coconut in coastal Andhra recorded a nut damage of 8.35%, whereas in Andaman and Nicobar Islands it was 12-27% nut damage. Rodent infestation rates in coconut plantations in A.P. were maximum in the month of October – November. In generals, peaks in nut damage were notice in the months of September and January during all the three years. In case of cocoa rodent infestation and pod damage varied throughout the season and peak rodent infestation was noticed during July (7.2 to 9.2%), September (7.8 to 7.9%) and December (6.2 to 6.5%) in coastal A.P.

Similarly in pineapple rodents inflicted 1.5- 8.87% damage in Arunachal Pradesh. In storage, rodents caused 2-5% damage. In Assam, the traditional storage structures like, *Duli* and *Mer* showed 22.2 and 14.3% loss in terms of spillage and structural damage. In Arunachal Pradesh rodent infestation reached maximum in October months and remained high in November to December (3.33 to 11.33 live burrows/ha). The damage to rice crop was up to 6.47% in East, West and Upper Siang districts.

Some very interesting observations on *B. bengalensis* from AP indicated their higher seasonal productivity during *kharif* season (>26 young ones/ female) as compared to the rabi season (>13 young ones/ female). In Assam, the infestation levels shoots quickly at harvesting stage (33.7 LBC/ha) as compared to that at maximum tillering stage (7.95 burrows/ha). Likewise, in A.P. the house rats inhabiting poultry farms breed @ 3.67 & 2.62 times in monsoon and winter seasons with an annual productivity of 53.1 young ones per female.

We all know that the fossorial rodents inhabit bunds. A simple but very useful observation revealed that more number of bunds (10/ 25 ha) with 0.6m size harbor more bandicoots as compared to less (4/ 12 ha) and smaller bunds of 0.30 m. Thus management of bunds alone can reduce 50% rodent infestation and therefore bund manipulation can be integrated with other rodent control techniques. UAS Bangalore and CIARI Port Blair center has initiated works on eco-biology of the largest rat of the country, i.e. *Bandicota indica* and Andaman rats, respectively. Burrowing behavior of *M. booduga, M. platythrix, T. indica* and *B. indica* has been completed. Similarly, CAZRI, Jodhpur attempted to understand burrowing patterns of Himalayan marmot inhabiting grasslands in Ladakh region.

Studies on botanicals have confirmed the anti-rodent properties in neem leaf powder, neem kernel powder, *Vitex nigundi* and *Polygonum* leaf powder against *R. rattus* and *B. bengalensis.* The baits containing *Polygonum* showed highest antifeeding index (66.6%) followed by neem (49.3%) and castor (47.2%). Similarly the application of ecodon solution @ 1 liter/burrow at maximum tillering stage and just before PI stage (rice) + sherman trap (30 traps/ha) after 10 days recorded the highest reduction (87.5%) in rodent population.

Studies at Ludhiana revealed a good potential of eucalyptus oil and citronella oil as repellents. Eucalyptus oil when applied as spray, paint and as encapsulated wax blocks @ 5, 10 and 20% at different intervals showed repellent action against house rats. Citronella oil also at 5, 10 and 20%, as paint, encapsulated wax blocks and spray, each with three modes of application i.e. daily, once a week and alternate days has revealed significant repellent effects on *R. rattus*.

A few chemicals were also evaluated as antifeedents against rodents by Punjab center. For example, exposure of *R. rattus* to baits containing 1, 2.5 & 5% cinnamic aldehyde for 3 days in bi-choice feeding test and then again after a gap of 7 and 14 days showed antifeedant effects. This effect was more pronounced with 5% concentration in both sexes. Similarly, the bioactivity of *trans*-Anethole essential oil compound of bitter fennel fruits also showed anti-feedant effects against *B. bengalensis* and *R. rattus* at concentration of 3% in bait. The anti-feedant index was strongest (69-77%) on first two days. Such results can be of great value in devising safer rodent management strategies. Likewise, ziram, a fungicide also showed repellent action against house rats.

The scientists have attempted antifertility studies with triptolide and Imidazole. The results indicated that feeding of triptolide in baits at 0.15, 0.20 and 0.25% to *B. bengalensis* for 15 days had male sterilant effects as was evident in significant reduction in weights of reproductive organs; sperm density, motility and viability with higher sperm abnormality even after 30 and 60 days of treatment. Similarly, intake of Imidazole treated baits @160 mg/kg for three days revealed fairly good palatability and sterility effects on male house rats.

Considering the limited number of registered rodenticides in India this house approved evaluation of new rodenticide molecules/ formulations. Therefore the Project evaluated two new anticoagulants viz., flocumafen (0.005%) and difencoum (0.005%) as wax block formulation as a part of coordinated trials. In laboratory both these chemicals registered cent percent kill of *R. rattus* and *B. bengalensis* in single day exposure within 5-6 days, however, in case of *T. indica*, flocumafen achieved cent percent mortality after two days exposure (in 6.4 days). Difenacoum on the other hand yielded only 50 % mortality (in *T. indica*) even after three days of exposure. In the choice tests they showed good palatability and acceptability registering 60-80% kill.

In Field trials under storage situations, two treatments with flocumafen (0.005%) and difencoum (0.005%) at fifteen days interval yielded satisfactory rodent control success in Rajasthan, Karnataka and Assam. In rice crop burrow baiting with flocoumafen (0.005%) achieved 60-74% control success, whereas difenacoum (0.005%) achieved 58-63% per cent control success in A.P and Karnataka. Likewise in coconut, both these rodenticides yielded 80-100% success in A.P. Karnataka and A&N Islands.

Studies from Ludhiana on rodent management in poultry farms indicated that 3 day baiting with bromadiolone (0.005%) and cholecalciferol (0.075%) as solo or as a combination at reduced dosages like; bromadiolone (0.00125%) and cholecalciferol (0.01%) yields almost similar control success (65-71%). However to minimize possibility of resistance factor against bromadiolone, the combination of the two can be a safer option in poultry farms. Studies in AP revealed that integration of chemical treatment (bromodiolone 0.005%) cake with mechanical method (sherman traps) resulted in 82 per cent rodent control success. In Assam the treatment with bromadiolone (0.005%) or ecodon @ 1:50 recorded 70-80% control success in poultry farms with in ten days.

Integration of acute (ZnP) and anticoagulant (bromadiolone) as a follow up treatment yielded 76 -82% rodent control success in rabi crops in arid regions. In most of the *kharif* crops, similar control success was obtained with single baiting with zinc phosphide, however for ground nut double baiting with ZnP and bromadiolone was required. In cocoa and coconut, integration of cultural practices with bromodiolone poison baiting and trapping proved to be most effective in reduction of nut damage to the tune of 81.2 and 75.0 per cent in cocoa and coconut plantations respectively. Polythene trunk banding in coconut proved highly effective in A.P. and Karnataka. The polythene banding was although economical but lasts for 2-3 years only in comparison to metallic bands which may last for 7-8 years.

The field evaluation of local bamboo trap (*maat chitap*) over mechanical trap registered increased tarp index (4-11%) than the Sherman traps (3-10%). The utilization of artificial barn owl nest boxes against rodent's activities revealed that a control success of 40% and 23 % in rice and wheat fields respectively.

Poly houses located in field areas suffers greatly due to rodent attack resulting into. 7.5-12.5% damage to flowering plants. Ragi based baits of zinc phosphide (2%) followed by bromadiolone (0.005%) baiting provided around 80% success, which was closely followed by use of snap trap @ 1/30 sq.ft, (67% success). The grape cultivation under drip irrigation experiences double threats from rodents, because the crops as well as the drip pipes are seriously damaged. Here also, the combination treatment of zinc phosphide followed by bromadiolone baiting proved the best yielding over 80% control success.

Project centers implemented social engineering activity on rodent control as part of farmers' participatory adaptive research in adopted villages. Regular awareness programs like on and off campus training and field demonstrations on rodent management technologies at farmers door steps were carried out. Project scientists arranged exhibitions on rodent management during Kisan Melas, Field Days etc at respective centers. Electronic and print media were also utilized for effective transfer of rodent management technologies.

Project scientists constitute a pool of experts and acted as resource for rodent management even in non-farm sectors, like railways, telecommunication, health sectors etc. The Project had a close liaison with several organizations. To name a few, we maintained a strong linkage with DAC, Dte of Plant Protection Quarantine and Storage, NIPHM, Hyderabad, NIBSM, Raipur, Haffkines Institute Mumbai etc. We organized one Expert Committee Meeting chaired by PPA in May 2012 at Jodhpur. Likewise, action plans for rodent pests and vector management for Chhattisgarh State was prepared and consequently technical support was provided to NIBSM, Raipur in organizing three Capacity Enhancement Programmes on Rodent Management during last year. The Project was a technical partner in National Plan on Rodent Pest Management hosted by NIPHM, Hyderabad during XI Plan period and a series of programmes, like workshops, trainings at various levels and demonstrations were successfully organized by NIPHM with our support. Though the DAC sponsored National Plan concluded in 2012, but our support to NIPHM still continues as our scientists have been supporting many of their programmes, like 21 days refresher trainings and National Trainings. Three such trainings were organized by Ludhiana, Jorhat and Maruteru centers during this period. A workshop on 'Current scenario of Rodenticides and their future outlook' organized by Food and Agribusiness School, Hyderabad was also cosponsored by the AINP. Besides the farm sector, we organized a Special Training on Rodent Management for Railway officials at Jodhpur. Recently we collaborated with Haffkines Institute, Mumbai in organization of a

training programme on Urban Rodent Management. As part of advisory and consultancy activity the Project generated additional resources of Rs 21 lakhs during the period under report.

At the end, I would like to express my deep sense of gratitude to Dr. S. Ayyappan, Secretary, DARE (GOI) and Director General, Indian Council of Agricultural Research, Dr J.S. Sandhu Dy. Director General (CS) and Dr P. K. Chakravarti, ADG (PP & B), ICAR, New Delhi for their guidance and encouragement and for providing financial assistance to the Project. Dr M.P. Singh, CTO (PP) from headquarters has been of great help in various project activities. Director, Central Arid Zone Research Institute, Jodhpur deserves special thanks for his expert advice, guidance, constant encouragement and support to this Project. I thank all the scientists and other staff members of all the cooperating centers for their support and untiring efforts in realizing the mandate of the Project. I am especially thankful to Dr Vipin Chaudhary, P.S., Mr R.C. Meena, Mr Surjeet Singh and Dr K.M. Gawaria the Senior Technical Officers and Mrs Rajni Mathur of Network Coordinating Unit, for their help in compilation and preparation of the Progress Report.

R.S. Tripathi

Network Coordinator

ICAR-Central Arid Zone Research Institute, Jodhpur

PART: I GENERAL INFORMATION

1. Name of the centre	Network Coordinating Unit ICAR-Central Arid Zone Research Institute, Jodhpur
2. Sanction No	1-2/77-PP dated 02.09.1977
3. Date of start	1977-78
4. Date of Termination	Network Project of continued nature
5. Report period	2012-13 to 2014-15
6. Scientist Incharge	Dr. R.S. Tripathi

7. Staff Position

Sr. No.	Name of post	No. of posts	Name of incumbent
I.	Network Coordinator	1	Dr R.S. Tripathi
II.	Principal Scientists	1	Dr Vipin Chaudhary, P.S.
III	Technical Assistants	3	Mr R.C. Meena, STO Dr K.L. Gawadia, STO Mr. Surjeet Singh, STO
IV	Driver	1	Mr Zakir Hussain, TA
V	Administrative	1	Mrs Rajni Mathur, LDC
VI	Supporting	2	Mr Babulal Mrs Ugma

PART II: WORK DONE

1. SURVEY AND SURVEILLANCE OF PEST RODENT IN ARID REGION

1.1. Cold arid region

Survey of rodents in crop fields, green houses and horticultural plantation located at various altitudes around Leh and shops and godowns located in Leh city were carried out. Besides, grass fields located at higher altitudes and barren area available near foothills at these altitudes were also surveyed for rodent species distribution. Main crops in the crop fields were wheat, barley, oats, alfa alfa and vegetables viz., potato, onion, cabbage, cauliflower, broccoli, cucurbits etc. In green houses vegetables viz, brinjal, capsicum, cucurbits, cabbage, cauliflower and cherry were the main crop. Apricot was the main fruit tree in the horticultural system. In godowns main commodity were rice and wheat. In crop fields trapping were carried out in a minimum of two canal area (1000 m^2) in village Sthakna (10899 ft), Chubi (11765 ft) and Stakmo (12112 ft). Field mice, *Mus booduga* was trapped from the all crop field irrespective of altitude. The same species were also encountered in the stores maintained in the fields for post-harvest storage. During September when crop was harvested and stacked in field below every stack 2-6 field mice (Av. 3.47 mice and 0.7 burrows/ stack) were encountered. Damage per ha due to presence of mice estimated to be 5kg/ ha/ day. About 50 mice were collect from four fields. Burrows of mice were also observed below some stacks, it was very simple with two burrow openings, one for entrance and other for exit. The burrows were very shallow with 6-8 inches depth and 2-2.5 ft long. Each burrow system was occupied by 2-5 animals. In field

storage only 3-4 four mice were trapped (Table1). From apricot no species of rodent was trapped. Grasslands (14000-17800) which were green and non-marshy with a water stream (valley) in between were mainly occupied by vole species. Voles were encountered from 14000-15000 ft, where their extensive burrows systems were found with as many as 24 (5-24/m^2) burrows in an m^2 area. Voles are colonial rodents and dug extensive burrow system with several openings. A single burrow system was occupied by a pair of vole, the burrows were shallow upto 8 cm deep, and we recovered single pair of voles from a burrow system. A single burrow system is usually spread in an area of 8-10 m with several intermediate openings and aggregation of openings at tip and end of burrow system for escape. Marmots, heavily bodied rodents weighing around 6-8 kg were observed upto 17700ft mainly in the barren pebbly lands at the foot hills of mountain. The burrow system of marmots was very extensive spread in an area of 15-20 meters with 4-5 openings. The diameter of burrow was 8-10 inch with a heap of soil at the mouth of burrow implicating that they dug very deep burrows. A single burrow system is usually occupied by a single marmot. Young ones remain with the mother and share the same burrow system. Marmot made the alarm call at the time of threat to caution other mates. In danger they rush into the nearest burrow opening for safety. The burrows of voles and marmots were well separated not overlapping though they share same habitat. Marmots prefer to burrow in a barren pebbly land, as more number of burrows was observed in barren pebbly land than grass land. Both the species survived on grasses and local vegetation including crops. In shops and godown a medium size species of *Rattus* species weighing around 90-200g were trapped (Table 2).

The pregnant females were manly collected in July-August only and September collection sub adults and lactating female more. Morphometric measurements and sex ratio of collected rodents are detailed in Table 2. The various species of rodent collected from cold arid region of Leh are detailed below.

Species collected from Cold arid Zone (Leh)

1. Field Mice, *Mus booduga* (Gray)

(Family: Muridae; Subfamily: Murinae)

Small size rodent weighing around 20-30g with tail slightly shorter than head body. Dorsal surface is dark brownish and ventral surface white in colour with soft fur.

Location: Crop field, field stores and houses located in fields. (Altitude: 11000 to 12000 ft; Villages: Sthakna, Chubi and Stakmo).

2. Turkesh Rat, *Rattus pyctoris* (Hodgson) (= *Rattus turkestanicus* (Satunin))

(Family: Muridae; Subfamily: Murinae)

Medium size rodent weighing around 150-200g with tail as long as head body. Dorsal surface is brown and ventral surface white in colour with coarse fur.

Location: Leh City. (Altitude: 11000ft; City area, FCI Godowns and Shops in the city).

3. Himalayan Marmot, *Marmota himalayana* (Hodgson)

(Family: Scuridae; Sub family: Surinae) Large size rodent weighing around 6000-7000g with robust body and short bushy tail. Dorsal and ventral surface is brownish in colour with soft fur.

Location: Grass field (*Cobarasia* sp) and barren land on foot hills (Altitude: 14000-17500ft; Villages: Muglat & Tangtse).

4. Voles, *Phaiomys leucurus* Blyth (=*Pitmys leucurus* (Blyth))

(Family: Cricetidae; Subfamily: Arvicolinae)

Small size rodent weighing around 25-35g with very short tail. Dorsal and ventral surface is brownish in colour with soft fur.

Location: Grass field (*Cobarasia* sp). (Altitude: 14000-15000ft; Villages: Muglat & Tangtse).

Table 1. Habitat wise rodent diversity and Trap index

S.No.	Habitat	Species trapped	Total No. trapped/observed	Trap index (Rodents/ trap/day)
1.	Crop fields & Horticultural plantation	Field mice (*Mus booduga*)	48	0.23
2.	Poly houses	Field mice (*Mus booduga*)	02	0.03
3.	**Storage**			
	a. Godowns & Shops	Turkesh rat (*Rattus pyctoris*)	07	0.07

	b. Field stores	Field mice (*Mus booduga*)	13	0.13
4.	Grassland/barren land on foot hills	Voles (*Phaiomys leucurus*)	06	0.15
		Marmots (*Marmota himalayana*)	05	-

Table 2. Mean body weight and other morphometric observations on rodent species collected from cold arid zone of Leh

Species	Mean ± SE					Wt. range (g)	Sex ratio (M:F)
	Body Wt (g)	***HB (mm)***	***HF (mm)***	***Ear (mm)***	***Tail (mm)***		
Phaiomys leucurus	28.16±2.07	107±1.75	18.83±0.48	5.83±0.31	29.17±0.40	22-32	1:1
Marmota himalayana	6660±393.68	470.20±10.25	101.0±1.87	55.0±2.23	142.4±4.27	5800-8000	1.5:1
Rattus pyctoris	140.0±14.70	177.14±6.15	32.03±0.59	16.29±0.29	179.86±6.07	90-200	1.3:1
Mus booduga	12.42±0.93	68.30±1.64	17.08±0.33	8.16±0.26	67.32±1.49	6-29	1.10:1

1.2. Hot arid region

1.2.1. Species Diversity: Regular survey and monitoring of rodent species through monthly trappings was continued in three major habitats (horticulture, silvi-pasture and crop fields & grasslands) in the Institute Central Research Farm. Indian gerbils, *Tatera indica* maintained its predominance during 2012, 2013 & 2014 with respective share of 79.79, 63.29 and 83.90% followed by five stripped squirrels, *Funambulus pennanti*, house rat, *Rattus rattus*, house mouse, *Mus musculus* (Table 3).Soft furred field rat, *Millardia meltada* (0.63%) was trapped during 2013. Typical burrow openings and pathways coupled with physical sighting revealed the presence of field mice, *Mus booduga* at periphery of crop fields, bush rat, *Golunda ellioti* on bushy bunds and Indian crested porcupine, *Hystrix indica* in grass land. Thus these three species showed minor occurrence. Based on earlier records of last four decades, the observations indicated complete replacement of true xeric species like *M. hurrianae*, *G. gleadowi* and *G. nanus*. *M. cervicolor* and four new species viz., *R. rattus, M. musculus M. booduga* and *G. ellioti* have entered the area. Secondly population of *T. indica* and *F. pennanti* has increased. The sex ratio in was in favour of males (Table 3)

1.2.2. Trap Index: Monthly trapping during the period (2012, 2013 and 2014) revealed a highest and lowest mean trap index of 5.37 & 1.30 rodents/ 100tarps/ day during, September and June, respectively. In general the trap index was more during monsoon (4.37-5.37 and less during summer (1.30-3.70). The rodent catch was comparatively less during the year 2014 and more during the year 2012 with a mean trap index 2.71 and 4.35, respectively (Table 4).

1.2.3. Habitat Preference: The fruit orchards (horticulture) were preferred more by the rodents as highest rodent population (mean 43.75%) was recorded in the Horticulture system followed by Silva-pasture (mean 29.35%) and Agri-pasture (mean 26.92%). Amongst these, *F. pennanti* was mainly trapped from horticulture fields followed by silvi-pasture block, whereas *T. indica* was almost uniformly trapped from all the three habitats. The two commensal species (*R. rattus* and *M. musculus*) were trapped mainly near the boundary wall of CR farm (Table 5).

Table 3. Rodent species composition in CR Farm during last three years

Rodent Species	1970	2012		2013		2014	
		% Compo-sition	*Sex ratio (M:F)*	*% Compo-sition*	*Sex ratio (M:F)*	*% Compo-sition*	*Sex ratio (M:F)*
T. indica	43.80	79.79	1:0.97	63.29	1:0.69	83.90	1:0.8
F. pennanti	0.82	14.26	1:1.45	31.65	1:0.61	13.56	1:0.78
R. rattus	0	4.26	1:0.33	3.16	1:1.5	1.65	1:1
M. musculus	0	1.60	1:0.50	1.27	1:1	0.85	-
M. meltada	0.82	-	-	0.63	-	-	-
M. hurrianae	28.90	-	-	-	-	-	-
G. gleadowi	0.82	-	-	-	-	-	-
G. nanus	24	-	-	-	-	-	-
M. booduga	0	Pr	-	Pr	-	Pr	-
G. ellioti	0	Pr	-	Pr	-	Pr	-
M. cervicolor	0.82	-	-	-	-	-	-
H. indica	-	-	-	-	-	Pr	-

Table 4.Monthly trap index (Rodents/100traps/day)

Months	2012	2013	2014
January	4.72	3.89	2.5
February	3.61	3.06	2.22
March	5.28	4.17	3.33
April	3.33	3.89	3.33
May	2.22	3.33	2.50
June	1.11	1.67	1.11
July	4.17	4.17	2.77
August	5.0	4.72	3.40
September	5.56	5.56	5.00
October	5.28	2.50	0.85
November	5.83	3.61	3.61
December	6.11	3.33	1.94
Mean	**4.35**	**3.66**	**2.71**

Table 5. Species composition of rodents in different cropping system

Year	% Abundance		
	Horticultural	***Silvi-pasture***	***Crop fields & grasslands***
2012	42.02	31.42	26.63
2013	39.24	35.44	25.32
2014	50.0	21.19	28.81
Mean	**43.75**	**29.35**	**26.92**

2. INCIDENCE OF BANDICOTA BENGALENSIS IN ARID REGION
(Location Specific)

2.1. <u>Population Dynamics</u>: Bi-monthly collection of *Bandicota bengalensis* from urban locales of Jodhpur city revealed further spread of the species in outskirts of the city area along the channel carrying city waste. The infestation in city area, railway station and mandis was very high compared to the outskirts. The mean trap index ranged between 0.043-0.078 rodents/trap/day during the reporting years with a maximum population in during November (Table 6). Females in the collection outnumbered the males and maximum females were trapped during the year 2013. The total bandocoots trapped during 2012, 2013 and 2014 were 66, 82 and 65, respectively. The collections during the years include mixture of adult & sub-adult population in almost all the months.

Table 6. Relative incidence of lesser bandicoots during the last three years

Years	**Trap index (Rodents/trap/day)**					
	January	***March***	***May***	***July***	***September***	***November***
2012	0.05	0.045	0.04	0.065	0.05	0.08
2013	0.067	0.078	0.11	0.056	0.04	0.083
2014	0.044	0.067	0.056	0.083	0.039	0.072
Mean	**0.054**	**0.063**	**0.069**	**0.068**	**0.043**	**0.078**

2.2. <u>Body Weight</u>: The body weight in the collection irrespective of year of collection ranged between 58-389 with lightest and heaviest female of 68 & 350g and male of 58 & 38g, respectively. Mean body weight of animals ranged from 194.00-271.75g, 178.6 -279.08 g and 181.43-259.50g during 2012, 2013 and 2014, respectively (Table 7a, b & c). Lower body weight was recorded in summer collections compared to that during monsoon and winters collections (Table 7a, b & c).

2.3. <u>Morphometry</u>: Various measurements of Head body (HB), Hind foot (HF), Tail (T) and Ear (E) lengths of *B. bengalensis* trapped from Jodhpur city are detailed in (Table 7a, b & c). Mean of various measurements of body during the year 2012, were HB: 184.21; HF: 37.35; Tail: 169.71; Ear: 18.18 mm; 2013 were HB: 191.55; HF: 36.86; Tail: 168.22; Ear: 17.61 mm and2014 were HB: 186.72 HF: 36.24; Tail: 162.79; Ear: 18.18 mm, respectively.

2.4. <u>Breeding Ecology</u>: The sexually mature male and females was available through the year, as in every catch more than 50% collection constituted sexually mature individuals. Similarly pregnant females were trapped round the year with a slight peak during monsoon and winter months (Table 8).

Table 7a. Mean body weight and other morphometric observations on *B. bengalensis* collected from Jodhpur during 2012

Trap Month	Body Wt.	HB	HF	Tail	Ear
January	214.30±25.21	180.30±7.56	38.00±0.92	161.10±5.80	17.60±0.49
March	227.11±10.21	192.78±4.21	35.22±1.03	169.45±7.68	17.78±0.38
May	253.88±33.91	178.25±13.74	38.38±1.09	172.75±5.57	18.50±0.87
July	194.00±28.57	175.85±8.24	35.38±1.09	162.54±6.28	17.46±0.84
September	252.90±13.58	185.40±10.18	38.10±0.86	169.99±6.00	18.20±0.54
November	271.75±17.36	192.69±5.24	39.00±0.60	182.62±5.80	19.56±0.55
Average	**235.66±5.31**	**184.21±1.34**	**37.35±0.30**	**169.71±1.42**	**18.18±0.14**

Table 7b. Mean body weight and other morphometric observations on *B. bengalensis* collected from Jodhpur during 2013

Month	Body wt (g)	HB (mm)	HF (mm)	Tail (mm)	Ear (mm)
January	279.08± 21.83	194.75± 5.10	39.00± 0.93	176.83± 5.08	19.42± 0.50
March	179.07±16.46	189.05± 6.55	35.86 ± 0.56	160.50± 3.72	16.00± 0.33
May	178.60 ± 25.16	169.15± 8.40	35.10 ± 1.19	155.90 ± 7.40	17.16 ± 0.66
July	240.30± 11.99	200.90± 2.69	37.20 ± 0.46	173.20 ± 2.08	17.20 ± 0.64
September	267.55±25.56	210.55± 7.40	37.45± 0.93	172.73 ± 5.54	18.00 ± 0.65
November	220.73 ±25.5	184.94 ± 6.75	36.60 ± 1.34	170.20± 5.29	17.93 ±0.82
Mean	**227.55±7.87**	**191.55±2.60**	**36.86±0.24**	**168.22± 1.50**	**17.61±0.21**

Table 7c. Mean body weight and other morphometric observations on *B. bengalensis* collected from Jodhpur during 2014

Trap Month	Body Wt.	HB	HF	Tail	Ear
January	259.25±13.30	196.25±2.15	37.25±0.57	158.50±3.21	19.88±0.27
March	259.50±12.95	199.25±3.66	37.83±0.60	170.25±4.10	19.58±0.39
May	199.10±19.97	180.60±6.90	36.30±1.24	164.10±17.45	17.30±0.63
July	221.07±19.88	195.20±1.54	36.13±.0.99	168.13±4.02	18.20±0.52
September	181.43±31.31	172.71±9.40	35.00±1.70	154.00±.7.66	17.29±0.91
November	203.85±21.99	176.31±9.04	34.92±0.75	161.77±7.20	16.85±0.47
Mean	**220.70±5.97**	**186.72±2.11**	**36.24±0.21**	**162.79±1.11**	**18.18±0.23**

Table 8. Seasonal Prevalence of Pregnancy (%) in lesser bandicoot rat

Years	Percent Pregnant females in the collection during months of					
	January	***March***	***May***	***July***	***September***	***November***
2012	33	50	50	43	40	56
2013	50	33	25	50	44.4	50
2014	60	33.33	25	50	40	42.86
Mean	**47.67**	**38.77**	**33.33**	**47.67**	**41.47**	**49.62**

3. IMPACT OF CANAL IRRIGATION ON CHANGE IN RODENT FAUNAL DIVERSIRY IN CANAL COMMAND AREAS

3.1. <u>IGNP Command Areas</u>: The surveys were undertaken in IGNP command areas at Netiwala (Sri Ganganagar), Suratgarh and Haryasar, Lunkaransar (Bikaner) and Bhand ka Dhora, Falodi (Jodhpur) to record rodent species composition, morphometry of the trapped rodents and extent of damage mung bean, cluster bean, ground nut, cotton and rice.

3.1.1. Species composition: The species identified through trapping or live burrows predominately were *Tatera indica* and *Meriones hurrianae* (Table 9), however the truly xeric species, *Gerbillus gleadowi* and *G. nanus*, trapped from IGNP areas of Jaisalmer district in previous year were not observed from the IGNP areas of Sriganganagar and Bikaner districts indicating their replacement due to irrigated cropping. *Millardia meltada,* a submesic rodent was trapped from cotton, ground nut and mung fields in Falodi and Lunkaransar areas. Truly mesic rodent species (*Mus booduga, Bandicota bengalensis* and *Nesokia indica)* were recorded from rice (Suratgarh); cotton, (Sri ganganagar) and ground nut (Lunkaransar).

3.1.2. Morphometry of trapped rodents: Seven rodent species were trapped from IGNP areas of Sri Ganganagar, Lunkaransar and Jaisalmer Districts. The detailed account of their body weight and measurements of different body parts are given in Table 9.

Table 9. Body weight, sex ratio and morphometry of trapped rodents

Species (N)	Body wt	Sex ratio	HB	HF	Tail	Ear
B. bengalensis(10)	186.6	1:1.5	175.5	37.3	166.4	17.5
N. indica (1)	175.0	-	158.0	30.0	98.0	20.0
T. indica (10)	125.1	1: 0.7	163.9	39.1	191.8	17.8
M. hurrianae (10)	76.9	1: 0.7	132.6	32.7	137.5	10.1
M. meltada (4)	77.3	1:1	139.75	24.75	154.25	18.0
M. booduga(3)	13.3	-	65.0	14.3	62.3	14.0
G. gleadowi (10)	32.3	1:1	93.1	28.4	131.2	10.3

3.1.3. Crop damage: Rodent infestation was observed in all the major kharif crops in the study locations (Table 10). In general the damage was more pronounced in periphery of crop fields. Groundnut crop proved highly vulnerable to rodent attack as the crop experienced an average damage of 12- 175% in both the study areas. The crop recorded maximum damage in peripheral areas (34.7%) in Lunkaransar. Cotton crop suffered up to 6.7% plant damage in Sri Ganganagar District. Mung registered 4.2 % (Lunkaransar) and 9.3% (Sri ganganagar) rodent damage. Similarly guar, an important cash crop of the region experienced lower damage in Sri Ganganagar (1.9%) than that in Lunkaransar (6.6%). Rice although infested with 1-6 burrows/m^2 in Suratgarh area experienced lowest mean rodent damage to tillers (0.9%), however one of the fields showed 14.3% tiller damage.

Table 10. Rodent species composition and crop damage in study areas

SN	Crops	Survey villages (District)	Mean damage (Max Damage)	LBC/ m^2	Rodent species
1	Cotton	Netiwala (Sriganganagar)	3.66 (6.7)	1-5	*B.b.; T.i,; N.i.; M.b.*
		Bhand ka Dhora (Jodhpur)	2.5 (.5.0)	1-4	*M.h.; T.i.; M.m.*
2	Groundnut	Haryasar/ Lunkaransar (Bikaner)	16.96 (34.7)	2-6	*T.i.; M.h.; N.i.; .M.b*
		Bhand ka Dhora(Jodhpur)	12.55 (13.0)	1-4	*M.h.; T.i.; M.m.*
3	Mung	Haryasar / Lunkaransar (Bikaner)	4.2 (4.84)	1-4	*T.i.; M.h.; M.m.*
		Netiwala (Sriganganagar)	9.33 (12.0)	1-5	*T.i., M.h.; B.b. N.i.*
4	Guar	Lunkaransar (Bikaner)	6.6 (12.12)	1-3	*T.i.; M.h.; N.i.*
		Netiwala (Sriganganagar)	1.91 (5.5)	1-2	*T.i.; M.h.; N.i.*
5	Rice	Suratgarh	0.9 (14.3)	1-6	*B.b.; T.i*

3.2. <u>Narmada Command Areas</u> : Survey was conducted during kharif and rabi season in Narmada Canal Command area to understand the rodent fauna vis-a-vis land use pattern. The study revealed that before the advent of canal the majority of farmers were mainly growing rain-fed crops; however some farmers were taking irrigated crops through open well system in limited area. After the advent of canal farmer started taking irrigated crops invariably during *rabi* along with rain-fed crops during *kharif*. Main crop in the area during *kharif* was, bajara, moong and castor, whereas in *rabi* mustard, wheat and cumin were the main crops. Some scattered damage due to nocturnal rodents inhabiting surrounding bunds was observed, which increased at crop maturity stage, when irrigation activities ceased and the rodents immigrate to the main field. The species of rodents encountered were Indian desert gerbil, *Meriones hurrianae*, Indian gerbil, *Tatera indica*, soft furred field rat, *Millardia meltada*, bush rat, *Golunda ellioti* and squirrels, *Funambulus pennanti* in the field and house mouse, *Mus musculus*, house rat, *Rattus rattus* in the *dhanis*, The mode of irrigation adopted by the farmers in the area was flood and sprinkler. Fields where cultivation of irrigated crops was in vogue for more than 20 years (i.e. through open well plus canal water) population/burrows of *M. hurrianae* was not observed, however the maximum rodents were trapped from these fields (Table 12). The fields where cultivation of irrigated crops started after advent of canal five years back (2008) activities of *M. hurrianae* was observed and in rain-fed crops and fallow lands along the canal *M. hurrianae* was the predominant species. Trapping data irrespective of habitat revealed the predominance of *T. indica* (30-44.44%) followed by *M. hurrianae* (20-33.33%) from crop fields, however from dhani (storage) infestation of *R. rattus* was recorded (Table11). The burrow density of *M. hurrianae* in these habitats was also very high (03 burrows per 1x1 m^2 sample). The mean trap index across the habitats was 2.58and 3.0 rodents/100 traps/day during 2013 & 2014, respectively (Table 12).

Table 11. Rodent species composition in the canal command area

Rodent Species	2013		2014	
	% Composition	Sex ratio M : F	% Composition	Sex ratio M : F
T. indica	30	1:2	44.44	1:1
M. hurrianae	20	1:1	33.33	1:0.66
R. rattus	20	1:1	22.22	1:1
M. musculus	10	-	Present	
M. meltada	10	-	-	
G. ellioti	10	-	-	
F. pennanti	Present	-	Present	

Table 12. Habitat wise Trap index

S. No.	Habitat	Trap index (rodents/ 100 traps/ day)	
		2013	2014
1.	Cultivation of Irrigated Crops in vogue for >30 years	5.0	6.67
2.	Cultivation of Irrigated Crops in vogue for last 05 years	3.3	3.3
3.	Cultivation of rainfed Crops only	3.3	3.3
4.	Natural Fallow	1.67	3.3
5.	Rainfed crop only in non- canal command area	1.67	Burrows of *M. hurrianae* was observed

4. EVALUATION OF RODENTICIDES

4.1. <u>Evaluation of new anticoagulant rodenticides :</u> Two new anticoagulant rodenticides viz., flocumafen and difencoum (0.005%) as wax block baits were evaluated against three major rodent species viz., *Rattus rattus, Bandicota bengalensis* and *Tatera indica* in laboratory (choice and no-choice trials) and also under field conditions. In no-choice feeding trial the experimental rodents were offered ready to use (wax block) bait of difenacoum (0.005%) and flocumafen (0.005%). Consumption of poison baits and (g/100g body wt.), per cent mortality, and days to death were worked out. Whereas, in choice trial the experimental rodents were given choice of difenacoum (0.005%) and flocumafen (0.005%) ready to use baits and plain food (most common grain of the area i.e. bajra).

4.1.1. Laboratory trials: Mortality data under no-choice trials revealed that difenacoum (0.005%) and flocumafen (0.005%) registered cent percent kill of *R. rattus* and *B. bengalensis* in single day exposure, however, in case of *T. indica* flocumafen (0.005%) achieved cent percent mortality after two days exposure whereas, difenacoum (0.005%) yielded only 50 percent mortality even after three days of exposure (Tables 13 & 15). Mean days to death after one day exposure of flocoumafen was 6.70 and 5.5 days for cent percent mortality of *R. rattus* and *B. bengalensis,* respectively, whereas for *T. indica* it was 6.4 days after 2 days exposure

(Table 15). Similar results were reported with difencoum yielding complete kill in 6.1 days (*R. rattus*) and 5.5 days *(B bengalensis*) (Table 13).

Extent of overall mortality and intake of poison bait were lower in choice test in comparison to no choice test. In the choice tests no significant difference was observed between the consumption of plain and poison bait by all the test species indicating that difenacoum (0.005%) and flocumafen (0.005%) baits were fairly well acceptable and palatable to all the test rodent species (Table 14 & 16). Percent mortality in choice tests after one day exposure with flocoumafen and difencoum was 80-90% in case of *R. rattus* and *B. bengalensis,* whereas similar mortality was observed in *T. indica* after 2 days feeding of flocoumafen, but difencoum proved ineffective (20% kill) even after 3 days exposure. Days to death ranged from 3-12 days for *R. rattus,* 5-15 days for *B. Bengalensis* and 3-14 days for *T. indica* in flocumafen (0.005%) treatment, whereas, in difenacoum (0.005%) treatment days to death for *R. rattus, B. bengalensis* and *T. indica* ranged, respectively from 3-10, 4-10 and 12-15 days (Table 14 & 16).

Table 13. Consumption of difenacom (0.005%) treated baits and mortality patterns in murids under no-choice test

S. No.	Feeding Period (Days)	Mean body weight Mean ± SE	Pre-treatment consumption g/100g body weight Mean ± SE	Poison consumption g/100g body weight Mean ± SE	Anticoagulant consumed (mg/kg) Mean ± SE	Mort-ality	Days to death	
							Mean± SE	*Range*
House Rat (*Rattus rattus*)								
1.	01	117.50 ± 7.90	8.73 ± 0.62	7.40 ± 0.54	3.70 ± 0.27	10/10	6.10 ± 0.77	3-10
Bandicoot rat (*Bandicota bengalensis*)								
1.	01	295.30 ± 10.02	8.09 ± 0.20	6.06 ± 0.25	3.03 ± 0.13	10/10	5.50 ± 0.58	2-8
Indian gerbil (*Tatera indica*)								
1.	02	154.50 ± 6.04	5.10 ± 0.14	4.39 ± 0.11	2.19 ± 0.05	2/10	7.50 ± 0.52	7-8
2.	03	159 ± 7.4	5.02 ± 0.21	4.10 ± 0.12	2.04 ± 0.06	5/10	10 ± 0.1.11	6-15

Table 14. Bait acceptability and mortality in murids given choice between plain and difenacoum (0.500%) treated pearl millet bait.

S. No.	Feeding period (Days)	Mean body weight Mean ± SE	Mean daily bait intake Mean ± SE			Paired student 't' test between 4&6 for significance	Mort-ality	Days to death	
			Poison		*Plain*			*Mean ± SE*	*Range*
			g/100g body weight	Anticoagulant consumed (mg/kg)	g/100g body weight				
House Rat (*Rattus rattus*)									
1.	01	123.80 ± 6.20	4.60 ± 0.66	2.30 ± 0.29	2.90 ± 0.42	Ns	8/10	6.50 ± 0.85	3-10
Bandicoot rat (*Bandicota bengalensis*)									
1.	01	288.30 ± 19.97	4.51 ± 0.69	2.25 ± 0.35	3.65 ± 0.84	Ns	8/10	7.63 ± 0.69	4-10
Indian gerbil (*Tatera indica*)									
1.	02	153.0 ± 13.40	3.38 ± 0.46	1.69 ± 0.23	4.64 ± 0.41	Ns	0/10	-	-
2.	03	160.70 ± 6.71	4.35 ± 0.46	2.17 ± 0.23	4.10 ± 0.23	Ns	2/10	13.5 ± 0.67	12-15

Table 15. Consumption of flocumafen (0.005%) treated baits and mortality patterns in murids under no-choice test

S. No.	Feeding Period (Days)	Mean body weight Mean ± SE	Pre-treatment consumption g/100g body weight Mean ± SE	Poison consumption g/100g body weight Mean ± SE	Anticoagulant consumed (mg/kg) Mean ± SE	Mort-ality	Days to death	
							Mean± SE	*Range*
House Rat (*Rattus rattus*)								
1.	01	141.0 ± 8.75	4.64 ± 0.17	4.14 ± 0.54	2.07 ± 0.25	10/10	6.70 ± 0.96	3-12
Bandicoot rat (*Bandicota bengalensis*)								
1.	01	257.30 ± 6.60	4.19 ± 0.19	4.18 ± 0.25	2.09 ± 0.16	10/10	5.50 ± 0.81	2-9
Indian gerbil (*Tatera indica*)								
1.	02	125.20 ± 2.70	5.31 ± 0.13	5.04 ± 0.19	2.51 ± 0.09	10/10	6.40 ± 0.62	3-10

Table 16. Bait acceptability and mortality in murids given choice between plain and flocumafen (0.500%) treated pearl millet bait.

S. No.	Feeding period (Days)	Mean body weight Mean ± SE	Mean daily bait intake Mean ± SE			Paired student 't' test between 4&6 for significance	Mort-ality	Days to death	
			Poison		*Plain*			*Mean ± SE*	*Range*
			g/100 g body weight	Anticoagulant consumed (mg/kg)	g/100 g body weight				
House Rat (*Rattus rattus*)									
1.	01	123.70 ± 6.29	3.76 ± 0.64	1.88 ± 0.32	3.40 ± 0.92	Ns	8/10	6.70 ± 0.60	3-12
Bandicoot rat (*Bandicota bengalensis*)									
1.	01	236.70 ± 3.42	2.72 ± 0.21	1.39 ± 0.10	1.01 ± 0.16	Ns	9/10	8.44 ± 1.05	5-15
Indian gerbil (*Tatera indica*)									
1.	02	113.0 ± 2.17	6.25 ± 0.74	3.12 ± 0.37	2.75 ± 0.19	Ns	8/10	5.91 ± 0.29	3-14

4.1.2. Field trials in Storage: Trials were conducted at grain mandi, Basin, Jodhpur, Rajasthan (26º18' N latitude and 73º1'30" E longitude) twice during summer (May-June, 2013) and winters (Jan-Feb., 2014). Three godowns each for respective poison of same size and uniform pest infestation were selected for investigations. Prior to poison baiting the areas were surveyed and plain baits and Sherman traps were laid for three consecutive nights to assess the extent of pest population/infestation. The live-trapped rodents were later released in the same habitat for further studies.

After assessing the pre-treatment pest population/infestation the ready to use poison baits (WB) of the two tests anticoagulant rodenticides viz., flocumafen and difenacoum (0.500%) were place uniformly on the runways of rodents for one day in all the sites of the study habitat. On average 10 bait stations (paper plates) were laid in each site of study habitat randomly and 25 g of bait of respective poison were provided in each bait station. Monitoring of the sites poisoned with anticoagulant rodenticides were initiated after three to four days and monitored continuously upto 14-15 days for dead rodents. On 4^{th} and 14^{th} day post treatment census was initiated in the sites poisoned with anticoagulant rodenticides. A second pulse of treatment with both the test rodenticide was provided on after 15 day of first pulse of treatment with same no. of bait stations with same amount of poison bait in each site. On 14^{th} day post treatment census was initiated in the sites poisoned with anticoagulant rodenticides. The consumption of poison baits for both the treatment was recorded.

Both the test rodenticides were evaluated by utilizing three assessment methods viz., census baiting, live burrow counting and trapping, simultaneously. Plain bajra (with 2% groundnut oil) was used as census bait during the trials. On average 10 bait stations (paper plates) were maintained randomly at an interval of 5-10 meter each and 15 bandicoot traps baited with pea nut butter were laid in the areas most frequented by rodents/runways in each

study site. The bait stations were checked at regular interval and consumption of bait recorded and replenished each time. Similarly traps were also checked regularly and trapped rodent were removed and traps were again laid after baited with peanut butter. Burrows located inside and outside the godowns were plugged and next morning reopened burrows were counted. The efficacy of rodenticides was evaluated using standard protocols. The results are as follows;

Trial-I: Three nights trapping yielded an average catch of 4.33 and 5.00 rodents per day, similarly mean consumption of bait per day per godown were 62.66 and 59.16 gm and no. of burrows (inside and outside godown) were 12 and 11.33 nos, at the sites to be treated with flocumafen and difenacoum, respectively. The pre-treatment data on pest infestation as evident from pre-treatment census indicated that infestation level of rodents was at par at both the test sites. The species composition as recorded through trapping in the study area revealed presence of four species, *B. bengalensis, R. rattus* and *M. musculus* from the storage site and *Tatera indica* outside the storage site.

Consumption of plain baits during census baiting prior to rodenticidal trials was 20.89 and 19.72/day/site from the sites to be treated with flocumafen and difenacoum, respectively. Similarly daily intake of poison bait of flocumafen and difenacoum (0.005%), respectively was 18.67 and 20.33 g/day/site during the first pulse of treatment, however the intake of both the poison was reduced to 12.67 and 13. 67 g/day/site, respectively for flocumafen and difenacoum (0.005%) during the second pulse of treatment. The effect of poison baiting with both the rodenticides seemed consistent as the percent control success obtained through three methods viz., census baiting, trapping and live burrow count was closely comparable (Table-17). Two treatment with Flocumafen (0.005%) at fifteen days interval yielded 48.93, 61.43 and 58.33% control success as assessed by census baiting, trapping and live burrow count method, respectively. Similarly, two treatments of Difenacoum (0.005%) yielded 49.29, 60.00 and 61.75 per cent control success with respective methods of assessment. The pooled data of the three methods revealed 56.23 per cent (with flocumafen) and 57.02 per cent (with difenacoum) control success after second pulse of treatment with respective test poison.

Trial-II: Like trial one the pretreatment data on pest infestation as assessed by burrow counting, census baiting and trapping methods revealed that (Table-18) infestation level of rodents in the study site was uniform. The species composition as recorded through trapping in the study area revealed presence of four species, *Bandicota bengalensis, Rattus rattus* and *Mus musculus* from the storage site and *Tatera indica* outside the storage site.

Consumption of plain baits during census baiting prior to rodenticidal trials was 13.67 and 14.87/day/site from the sites to be treated with flocumafen and difenacoum, respectively. Similarly daily intake of poison bait of flocumafen and difenacoum (0.005%), respectively was 14.67 and 12.67 g/day/site during the first pulse of treatment and the intake of both the poison during the second pulse of treatment was at par with first pulse of treatment, 12.00 and 13. 00 g/day/site, respectively for flocumafen and difenacoum (0.005%). The effect of poison baiting with both the rodenticides seemed consistent as the percent control success obtained through three methods viz., census baiting, trapping and live burrow count was closely comparable (Table-18). Two treatment with Flocumafen (0.005%) at fifteen days interval yielded 54.66, 55.66 and 51.98% control success as assessed by census baiting, trapping and live burrow count method, respectively. Similarly, two treatments of Difenacoum (0.005%) yielded 58.20, 54.49 and 51.17 per cent control success with respective methods of assessment. The pooled data of

the three methods revealed 54.04 per cent (with flocumafen) and 54.62 per cent (with difenacoum) control success after second pulse of treatment with respective test poison.

Anticoagulant rodenticides being chronic in action caused delayed death in the target animals. The mortality in the test sites poisoned with flocumafen and difenacoum started from day 3-5 day and continued upto 21^{th} day.

Based on the field studies it may be concluded that both the anticoagulant rodenticides are quite efficacious in tackling rodents infesting godowns. Two treatment of both the test poison yielded an over control success of 56.23 (flocumafen) and 57.02 (difenacoum) percent. At par consumption of poison and plain bait (pre bait consumption) revealed that the acceptability of both the poison is very good.

Table 17. Field evaluation of anticoagulant rodenticides in grain mandi (Trial-I)

Treatments	Census baiting				Trapping				Burrow Counting				Mean success by different methods
	Av. Bait consumption/site (g)			*Control success (Per cent)*	*Mean animals trapped per day (Nos)*			*Control success (Per cent)*	*Mean nos. of burrows reopened*			*Control success (Per cent)*	
	Pre-treatment	*Post treatment**			*Pre-treatment*	*Post treatment**			*Pre-treatment*	*Post treatment**			
		I st Pulse	*II nd Pulse*			*I st Pulse*	*II nd Pulse*			*I st Pulse*	*II nd Pulse*		
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
Flocumafen (0.005%)	62.66	37.90	32.00	48.93	4.33	2.33	1.67	61.43	12.00	7.00	5.00	58.33	56.23
Difenacoum (0.005%)	59.16	34.61	30.00	49.29	5.00	2.66	2.00	60.00	11.33	6.00	4.33	61.75	57.02
Mean	60.91	36.26	31.00	49.11	4.67	2.50	1.84	60.72	11.67	6.50	4.67	60.04	56.63

Table 18. Field evaluation of anticoagulant rodenticides in grain mandi (Trial-II)

Treatments	Census baiting				Trapping				Burrow Counting				Mean success by different methods
	Av. Bait consumption/site (g)			*Control success (Per cent)*	*Mean animals trapped per day (Nos)*			*Control success (Per cent)*	*Mean nos. of burrows reopened*			*Control success (Per cent)*	
	Pre-treatment	*Post treatment**			*Pre-treatment*	*Post treatment**			*Pre-treatment*	*Post treatment**			
		I st Pulse	*II nd Pulse*			*I st Pulse*	*II nd Pulse*			*I st Pulse*	*II nd Pulse*		
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
Flocumafen (0.005%)	41.00	20.67	18.67	54.46	3.00	1.67	1.33	55.66	8.33	4.67	4.00	51.98	54.04
Difenacoum (0.005%)	44.67	23.33	18.67	58.20	3.67	2.00	1.67	54.49	9.67	5.33	4.67	51.17	54.62
Mean	42.84	22.00	18.67	56.33	3.34	1.84	1.50	55.08	9.00	5.00	4.34	51.58	54.33

*Note: * Control success was evaluated 14 days after each treatment*
Mean of three replications

4.2. Evaluation of repellent/ deterrent against *Rattus rattus*

4.2.1. Laboratory Trials: Ziram (27 SL), a fungicide was evaluated for its repellent/deterrent properties against house rat (*Rattus rattus*) in laboratory. Two sets of experiment in plus maize and cages were carried out. In each plus maze in arm no. 1 & 3 Ziram treated bait (3% mixed in pearl millet) and arm no. 2 & 4 with plain bait (pearl millet) was kept and each components was replenished after 24 hrs continuously for four days. Single house rat was released in each maze and response of house rat towards treated bait was monitored from 10 am to 5 pm at 30 minute interval for all the four days. Another trial in cages with six replications was also laid to evaluate the repellent/deterrent effect. The test rodents were offered Ziram (2 & 3%) prepared in pearl millet for seven days.

The observation of the plus maze study revealed that rodents spent most of their time in the arms where plain bait was kept. The consumption of treated bait in all the sets were nil, however per day plain bait consumption ranged from 1.95 to 2.45 g/100 g body weight, which was significantly lower than pre bait consumption (3.83 to 4.53 g/100 g body weight) indicating that availability of treated bait has altered the plain bait consumption in test rodents. 2-10 g reduction in body weight of test rodents within four days was also recorded (Table 19). Ziram treated bait at 2 and 3% conc. was completely rejected by the test rodents, as during the exposure period of seven days none of rodent even touched the treated bait, however the plain was consumed in the range of 4.37 to 5.23 and 4.19 to 4.67 g/100g body wt when offered with treated bait at 3 and 2%, respectively (Table 20). The plain bait consumption during the treatment period was almost at par with that of pre-treatment consumption revealing that availability of treated bait has not altered the rodent behavior towards bait as presumed in previous test.

The observations therefore revealed that ziram at 2 and 3 per cent concentration in pearl millet bait was not preferred at all by the house rat indicating repellent/deterrent effect on the house rat.

Table 19. Evaluation of Ziram against House rat (*Rattus rattus*) in plus maze

Set No.	Feeding period (Days)	Initial body weight (gm)	Final body weight (gm)	Reduction in body wt. (gm)	Consumption g/100g B. Wt.		
					Pre-Treatment	Treatment	
						Plain	*Poison*
1.	04	125.00	120.50	4.50	4.53	2.45	0.0
2.	04	128.00	126.00	2.00	4.21	2.18	0.0
3.	04	134.00	130.70	3.30	4.22	2.70	0.0
4.	04	160.00	150.00	10.00	3.83	1.95	0.0

Table 20. Evaluation of Ziram against House rat (*Rattus rattus*) when given choice between Ziram (2 & 3%) treated and plain bait in pearl millet.

S. No.	Feeding period (Days)	Mean body weight Mean ± SE	Consumption g/100g B. Wt (Mean ± SE)		
			Pre- Treatment	Treatment	
				Plain	*Poison*
2%					
1.	07	126.75 ± 10.31	4.22 ± 0.37	4.79 ± 0.19	0.0
3%					
1.	07	135.00 ± 7.94	4.45 ± 0.18	4.46 ± 0.11	0.0

4.2.2. Evaluation in simulated storage condition: In simulated storage condition two experimental sets were maintained, in one set stacked grain filled bags were sprayed with ziram 3% and in other set ziram (3%) was applied on wall and floor of cage where simulated storage condition was created. The effect of pesticide was same as observed in laboratory trials. In both the experimental conditions the test rodent foraged around the bags but never tried to damage the gunny bags for feeding on grains stored in it. In other words though the rat has access to the bags yet never tried to damage them in search of food. In test set where the ziram 3% was sprayed on bags the rat died on 5th day due to starvation (Fig. 1), whereas in second set where the ziram 3% was applied at one end on the wall and floor of cage (Fig. 2) the bags were not damaged but the rat survived on the grains spilled out from the bag due to its nocturnal foraging activity.

4.3. Evaluation of Zinc Phosphide (40%)

A new formulation of Zinc Phosphide (40%) against three major rodent species viz., *Rattus rattus, Bandicota bengalensis* and *Tatera indica* in laboratory under choice and no choice trials. The test rodenticide, zinc phosphide (40% a.i.) was evaluated at three concentrations, viz., 1.0, 2.0 and 4.0% in baits. These concentrations were made by mixing desired quantities (w/w basis) in ground nut oil (2%) smeared *bajra* grains. Two types of feeding trials, viz., no-choice and choice trials were conducted on all the three test species using three different test concentrations in laboratory. In no-choice feeding trial, test animals were separately exposed only to the three (1, 2 and 4 %) concentrations of zinc phosphide (40%) bait in bajra for one day. Whereas, in choice condition an alternate pain food was also offered along with various concentration of test poison to all replications of the test species for one day exposure period. Water was available *ad libitum* in both the trials. After treatment the survived test rodents were offered plain food along with water. Consumption of bait for pre-treatment and during treatment and post-treatment periods was measured and observation on symptoms of poisoning and hours to death was recorded.

FIG.1. ZIRAM 3% SOLUTION SPRAYED ON THE BAGS

Stacked Gunny bags sprayed with 3% Ziram solution

Rattus rattus released in cage

Rattus rattus died of starvation (no damage to bags)

FIG. 2. ZIRAM 3% SOLUTION APPLIED ON THE WALLS AND FLOOR AND BAGS

Gunny bags stacked in the area with walls and floor applied with 3% Ziram Solution

Rattus rattus released in the cage

Rattus rattus hiding itself within the bags
without inflicting damage

4.3.1. Laboratory trials: Mortality data revealed that after consumption of zinc phosphide (40%) treated baits in various concentrations (1, 2 and 4 per cent) all the test rodent species died in a few hours (0.5-9 hrs). It indicates that, being an acute poison, the new formulation of zinc phosphide (40%) is extremely potent in knocking down the test rodents. The respective mean period for 100 % mortality at 1, 2 and 4 percent concentration of test rodents were 3.80, 3.20 and 1.17 hours for *B. bengalensis*; 4.80, 2.65 and 1.25 hours for *R. rattus* and 6.15, 5.80 and 1.30 hours for *T. indica*. Therefore the mortality period was quickest (mean: 1.17- 1.30 hrs) at highest test concentration (4%) and longest with lowest concentration (1%). The intake of poison bait during one day exposure period at 1, 2 and 4% concentration was 0.93,0.87,0.65 g/100 g body wt., respectively for *B. bengalensis;* 1.27,1.27 and 0.83g/100 g body wt., respectively for *R. rattus* and 1.33, 1.31 and 1.14g/100 g body wt., respectively for *T. indica.* Thus the consumption poison bait by all the test species was less at 4 percent, whereas, it was almost at par at 01 and 02 percent concentrations (Table 21). Based on the data on poison bait intake, the a.i. ingested for 100 kill in various test species ranged between 0.93 (*B. bengalensis*) and 1.33 mg/kg (*T. indica*) at 1 percent concentration; 1.75 (*B. bengalensis*) and 2.61 mg/kg (*T. indica*) at 2 percent concentration (Table 21). Likewise at 4% concentration, the values ranged between 2.59 (*B. bengalensis*) and 4.45 mg/kg (*T. indica*). *R. rattus* recorded mid values of 1.27, 2.55 and 3.31 mg/kg for respective test concentrations

The lesser bandicoot rats, *B. bengalensis* proved most susceptible as complete kill was achieved in comparatively less period with less ingestion of poison at all the test concentrations (Table 21). Whereas, Indian gerbils, *T. indica* took more time in achieving complete kill of gerbils at all the test concentrations with comparatively more ingestion of poison (Table 21).

In presence of alternative food the relative consumption of plain and poison treated baits in choice feeding (Table 22) did not revealed any significant variability by any of the test species for all the test concentrations. It clearly indicated that the pearl millet based poison bait of zinc phosphide (40%) is fairly acceptable by all the three test rodent species. Secondly, the poison bait consumption in all the test species showed a uniform trend at various concentrations. It was maximum at lowest concentration (1%) i.e., 1.05 (*B. bengalensis*); 0.97 (*R. rattus*) and 0.75 g/100 g body wt. (*T. indica*) and was least at highest test concentration (4 %) i.e., 0.53 (*B. bengalensis*) 0.60 (*R. rattus*) and 0.64 g/100 g body (*T. indica*). As expected, the ingestion of active ingredient of zinc phosphide showed a reverse trend in all the test species for all the test concentrations. The data presented in Table 22 indicated that it was more for highest concentration (4 %) and least for lowest concentration. The mortality was between 70-90 percent in *B. bengalensis* and *R. rattus* and 60-80 per cent in *T. indica*. At 2 and 4% concentrations, 90 percent *B. bengalensis* and *R. rattus* succumbed to the poison within 1-5 hours however, at the lowest test concentration (1%), it took 2-6 hours to achieve 70 percent mortality in these rodents. In *T. indica* the mortality was least, only 60 per cent gerbils succumbed to the poison at 1 % concentration within 3-10 hours. Maximum kill of 80 percent

was achieved at 2 and 4 % concentration within 4-9 hrs and 0.5- 2 hours, respectively (Table 22).

The new formulation of zinc phosphide (with 40% a.i.) proved very effective as in no-choice test cent percent kill was achieved in all the test rodent species at all the test concentrations (1, 2 and 4 per cent) of pearl millet based poison baits. In presence of an alternate plain food also (choice trials), the mortality was between 70-90 % (*B. bengalensis* and *R. rattus*) and 60-80% (*T. indica*). Likewise the intake of poisoned baits and plain bait was at par, indicating the fairly good acceptability and palatability of poison baits.

Table 21. Bait consumption and mortality pattern in different species of rodents feeding on zinc phosphide (40%) treated pearl millet baits in no-choice test.

S. No.	Mean body weight Mean ±SE	Conc. (%)	Pre-treatment plain bait consumption (g/100g bw. Wt.) Mean ±SE	Poison bait consumed (g/100g bw. Wt.) Mean ±SE	Poison ingested (mg/Kg) Mean ±SE	Mortality	Hrs to death	
							Mean ±SE	*Range*
Bandicota bengalensis								
1.	231.0±7.4	1	4.02±0.11	0.93±0.13	0.93±0.13	10/10	3.80±0.47	2-6
2.	218.20±9.43	2	4.66±0.11	0.87±0.16	1.75±0.31	10/10	3.20±0.55	1-6
3.	254.0±10.81	4	4.20±0.12	0.65±0.10	2.59±0.38	10/10	1.17±0.24	0.5-2.5
Rattus rattus								
1.	94.10±4.60	1	4.99±0.19	1.27±0.18	1.27±0.18	10/10	4.80±0.77	2-8
2.	112.3±4.80	2	4.93±0.17	1.27±0.22	2.55±0.44	10/10	2.65±0.57	1-7
3.	117.80±6.30	4	4.46±0.14	0.83±0.13	3.31±0.50	10/10	1.25±0.15	0.5-2
Tatera indica								
1.	110.40±4.20	1	5.45±0.15	1.33±0.17	1.33±0.17	10/10	6.15±0.69	3-9
2.	128.0±6.98	2	4.49±0.16	1.31±0.25	2.61±0.49	10/10	5.80±0.66	3-9
3.	109.0±4.16	4	4.73±0.18	1.14±0.10	4.45±0.39	10/10	1.30±0.19	0.5-2

Table 22. Bait acceptability and mortality in different species of rodents given choice between plain and zinc phosphide (40%) treated pearl millet baits

S. No.	Mean body wt Mean ±SE	Conc. (%)	Bait consumed (g/100g bw. Wt.) Mean ±SE		Significance (I & II)	Poison ingested (mg/Kg) Mean ±SE	Mortality	Hrs to death	
			Poison bait (I)	*Plain Bait (II)*				*Mean ±SE*	*Range*
Bandicota bengalensis									
1.	203.50±10.72	1	1.05±0.24	0.93±0.47	>0.05 (NS)	1.05±0.24	7/10	3.0±0.37	2-5
2.	247.50±10.32	2	0.77±0.17	0.77±0.29	>0.05 (NS)	1.54±0.33	9/10	2.75±0.44	2-5
3.	280.90±9.50	4	0.53±0.08	0.51±0.16	>0.05 (NS)	2.13±0.32	9/10	2.11±0.22	1-2.5
Rattus rattus									
1.	101.20±4.90	1	0.97±0.26	1.16±0.54	>0.05 (NS)	0.97±0.26	7/10	3.86±0.56	2-6
2.	125.0±4.61	2	0.75±0.12	1.16±0.21	>0.05 (NS)	1.49±0.24	9/10	2.06±0.22	1-3
3.	119.30±6.55	4	0.60±0.11	0.65±0.31	>0.05 (NS)	2.41±0.43	9/10	1.70±0.26	0.5-3
Tatera indica									
1.	112.30±4.41	1	0.75±0.28	2.06±0.62	>0.05 (NS)	0.75±0.28	6/10	7.20±0.86	3-10
2.	116.0±4.65	2	0.68±0.17	1.76±0..37	>0.05 (NS)	1.37±0.33	8/10	6.86±0.62	4-9
3.	111.7±5.21	4	0.64±0.14	0.73±0.38	>0.05 (NS)	2.54±0.54	8/10	1.31±0.16	0.5-2

5. SOCIAL ENGINEERING ACTIVITY ON RODENT CONTROL

5.1. <u>Bheenjwadia village</u>: Rodent survey and four demonstrations on kharif crops and three demonstrations on rabi crops was organized on rodent management technologies and rodenticidal evaluations at farmer's fields were conducted in Bheenjwadia village of Jodhpur District. The studies revealed infestation of two predominant rodent species viz., *Meriones hurrianae* and *Tatera indica*. The level of infestation was almost similar in both the study season. On farm training on rodent extent of rodent problem, the rodent species of the region, techniques for preparation and application of poison baits and precautions etc was organized.

<u>During 2012:</u> Four demonstrations on kharif crops and three demonstrations on rabi crops were organized on rodent management technologies and rodenticidal evaluations at farmer's fields. The results of the field demonstrations on rabi crops indicated that rodent control success with zinc phosphide was 67.27, 62.50 and 63.79 percent in mustard, wheat and cumin, respectively on 4th day after treatment. On the other hand, as expected single baiting with bromadiolone yielded only 23 to 28 percent success and increased to 61.53(mustard), 64.81 (wheat) and 63.15 % (cumin within 2 weeks. However, in zinc phosphide treatment the success was reduced to 57.41, 55.35 and 51.72% in respective crops on 15th day after treatment. The double baiting which integrates acute and chronic rodenticides recorded highest rodent control success of 73.68 % (mustard,) 72.00 % (wheat) and 71.15% cumin on 4th DAT which increased to 78.9, 80.0 and 76.9 percent on 15th DAT. The control fields, rather registered increase in rodent infestation (14 to 18 %). The seed yield increased by 5.96, 8.54 and 8.93 percent due to rodenticidal treatment in mustard, wheat and cumin respectively. During kharif season the studies indicated that rodent control success with zinc phosphide was 48 to 66.66 % in pearl millet, mung bean, moth bean, cluster bean and groundnut on 4th day after treatment. Control success in groundnut was the least due to typical crop phenology providing safe shelter to rodents. Therefore it requires repeat applications. Increased in grain yield by 4-7 % was noticed in different kharif crops due to rodenticidal treatment compared to control.

<u>During 2013:</u> Four field demonstrations on rodenticidal evaluation in *kharif* crops (bajra, mung, moth, cluster bean and ground nut (in 2013) and three demonstrations on *rabi* crops (Mustard, wheat and cumin in 2012-13) were organized in the village. In the *rabi* crops four treatments, viz., zinc phosphide (2%), bromadiolone (0.005%) and zinc phosphide(2%) followed by bromadiolone (0.005%) and an untreated control were imposed. In the *kharif* crops only zinc phosphide (2%) with an untreated control were demonstrated. Based on the experiences of previous two years another treatment of zinc phosphide (2%) followed by bromadiolone (0.005%) was also added in ground nut crop this year. The baits were freshly prepared by farmers using bajra grains and ground nut oil.

The results of the field demonstrations on *rabi* crops indicated that rodent control success with zinc phosphide was 68.52, 62.26, and 67.86 per cent in mustard, wheat and cumin, respectively on 4^{th} day after treatment, whereas with bromadiolone it was only 25.0, 21.57 and 27.78 per cent in respective crops. However being a chronic rodenticide, the success with bromadiolone treatment increased to 61.54, 62.75 and 61.11 per cent after 15 day of first treatment. The double baiting where acute rodenticide (zinc phosphide) was integrated with application of chronic bromadiolone, the success rate was 71.15- 73.58 percent on 4 DAT which increased

further to 76.92-81.82 per cent (15 DAT). In the untreated control plots the rodent infestation increased from 12-16% during this period. Due to rodenticidal treatments the seed yields recorded an increase of 4.57, 6.89 and 8.33% in comparison to control in mustard, wheat and cumin crops, respectively.

In the *kharif* crops where only one rodenticide baiting (zinc phosphide 2%) was imposed, the rodent control success was 66.04 (bajra); 64.81 (mung); 63.63 (moth) and 62.5 per cent (cluster bean) on 4 DAT. The success rate in these crops dropped to 58.49, 62.96, 54.55 and 55.36 % on 15 DAT. The crop yields, due to zinc phosphide treatment were however increased to 4.35 % (bajra); 7.02% (mung); 8.33% (moth) and 5.45% (cluster bean). Due to typical phenology of crop, ground nut registered least control success (49.15%) on 4 DAT and 40.68% on 15 DAT with single treatment of zinc phosphide. However with a follow up treatment of bromadiolone after zinc phosphide baiting, the rodent control success was increased to 80.65% on 15 DAT. It indicated that ground nut crop due its longer duration and typical phenology, integration of acute (zinc phosphide) and chronic rodenticide (bromadiolone) is more effective than the solo treatment with zinc phosphide. The untreated fields recorded increased rodent infestation to the tune of 12-18% during this period. The treated fields gave 4.44% higher yields over the untreated control.

During 2014: Field demonstration on rodenticidal baiting in farmers' field yielded rodent control success from 62 to 66 per cent with single baiting of zinc phosphide in various kharif crops like pearl millet, mung bean, moth bean, cluster bean on 4 days after treatment, whereas, it was only 48.27 per cent in groundnut. A follow up treatment was therefore required in groundnut with bromadiolone (0.005%) after zinc phosphide baiting, which increased the control up to 80 percent after 15 DAT. Integration of acute rodenticide (zinc phosphide) with an anticoagulant rodenticide, bromadiolone as a follow up treatment in rabi crops also proved best in registering 77.77 to 81.48 percent control (mustard, wheat and cumin). The seed yield increased by 4 to 7 percent in *kharif* (2014) and 4 to 8 percent in *rabi* crops during 2013-14 season.

6. TRANSFER OF TECHNOLOGY

6.1. During 2012-13

Following off and on campus training in collaboration with KVK was organized on Rodent Pest Management in field and storages along with two demonstrations and one anti-rodent campaign.

i) Off campus training programme on Rodent Pest Management

S.No.	Title	Village	Date	Participants
1.	Rodent management in field and grain storages	Gulabsagar	03/10/12	16
2.	Rodent management in grain storages	Purkhawas	23/01/13	22
3.	Rodent management in grain storages	Gulabsagar	11/02/13	26
			Total No of beneficiaries	**64**

ii) Lecture during on campus training programmes conducted at KVK Jodhpur

S.No.	Date	Topic	Training programme	Participants
1.	18/10/12	Rodent management in crops	Crop diversification 16-20 Oct. 2012, ATMA., Tonk	32
2.	3/11/12	Rodent management in crops	P.P measures in Mustard and gram 30/10 -3/11/12, ATMA, Tonk	29
3.	5/11/12	Rodent management in crops	Krishak Mitra Training 4-5 Nov.2012, ATMA, Jodhpur	34
4.	9/11/12	Rodent management in fruit crops	Horti. Based crop production system. 5-9, Nov.2012 ATMA, Bilwara	30
5.	22/11/12	Rodent management in rabi crops	Integrated farming system 19-23 Nov, 2012 ATMA, Bilwara	32
6.	02.03/13	Rodent management in crops	Ag. Supervisors training programme 25.2.13 -10.03.13 ATMA, Jodhpur	35
Total No of farmers benefited				**192**

iii) Demonstration conducted on Rodent Management

S. No.	Problem	Technology provided	No. of demons. conducted	Name of village	Results
1.	To reduce rodent population in fields	Use of poison bait of Zinc phophide	28	Purkhawas Luni, Jodhpur (kharif 2012)	Reduced 35-40% rodent population in field
2.	To reduce rodent population in grain storages	Use of Bromodilone cake	40	Purkhawas, Luni, Jodhpur	Reduced 20-25% rodent population in grain storages.

iv) Anti- rodent Campaigns

S.No.	Title of campaigns	Place	Date	Participants
1.	Rodent control campaigns	Village Purkhawas, Luni, Jodhpur	29/06/12	71

6.2. During 2013-14

Training on rodent management was imparted to the farmers of Bramsar village (Jaisalmer) and Golasan, Silu, Paladi, Hadacha villages in Sanchor, about 20-25 farmers participated in each such trainings. Besides, lectures on Rodent Pest Management were delivered in on campus training organized by KVK and two radio talks were delivered on AIR.

i) Off campus training programme on Rodent Pest Management

S. No.	Title of Training	Date	Village	No. of Participants
1.	Rodent control in fields and grain Storages.	27.08.2013	Gulabsagar (Jodhpur)	25
2.	Rodent control in fields and grain Storages.	03.10.2013	Purkhawas (Jodhpur)	26
3.	Rodent control in fields and grain Storages.	06.11.2013	Purkhawas (Jodhpur)	28
4	Training on Rodent Pest Management in Farmers'– Scientist interactive Meet	12.6.13	Bhujawal (Jodhpur)	25
5.	Training on Rodent Pest Management in Farmers'– Scientist interactive Meet	26.6.13	Bhramsar (Jaisalmer)	22
6.	Farmer Scientist Interaction on Plant Protection Measures for Kharif and Rabi crops	3.9.13	KVK Pali	30
ACTIVITY UNDERTAKEN BY COORDINATING UNIT				
7.	Training on Rodent Pest Management	26-29.12.13	Silu, Golasan, Hadacha (Jalore)	20
8.	Training on Rodent Pest Management	13-15.2.14	Silu, Hadacha, Paldi (Jalore)	15
			Total No of beneficiaries	**191**

ii) Lecture during on campus training programmes conducted at KVK Jodhpur

S.No.	Lecture delivered	Title of Training	Date	No. of Trainees	Resource person
1.	Rodent control in fruit plants.	Fruit production technology in arid zone. (05.08.2013- 8.08.2013)	08.08.2013	42	Dr. Vipin Chaudhary
2.	Rodent control in Kharif crops.	Plant Protection measures in kharif crops. (23.08.2013)	23.08.2013	49	Dr. R. S. Tripathi
3.	Rodent Sp. in Rajasthan and its behaviour.	Plant Protection measures in kharif crops. (23.08.2013)	23.08.2013	49	Dr. Vipin Chaudhary
4.	Rodent control in rabi crops.	Improved Agri. Technologies in rabi crops. (17.12.2013-21.12.2013)	21.12.2013	23	Dr. R.S. Tripathi

iii) Demonstrations conducted on Rodent Control

S. No.	Problem/Activity	Technology provided	Village	No. of Demo Con.	Results
1.	To reduce rodent population in grain Storages.	Use of Bromodiolone cake	Purkhawas	52	Reduced 25% rodent population.
2.	To reduce rodent population in fields.	Use of Zinc phosphide based poison bait (@ 20g/ kg Grain)	Purkhawas	03	Reduced 35% rodent population.

iv) Anti-rodent campaign

S. No.	Campaign	Village	Date	No. of Participants		
				Male	Female	Total
1.	Rodent control	Purkhawas	18.06.2013	41	18	59
2.	Rodent control	Purkhawas	17.01.2014	48	14	62

v) Radio Talks

S.No.	Title	Date of Broadcast
1.	खेत–खलिहानो में चूहा नियंत्रण कितना आवश्यक	12.05.13
2.	किसानो का दुशमन चूहा	23.11.13

6.3. During 2014-15

A field based training on 'Rodent Pest Management" was also organised at Leh. About 60 farmers participated in the training. Training on rodent management with demonstration on bait preparation and bait delivery technique was given to farmers of village Beenjwadia & Sawalnagar (Jodhpur), Golasan & Silu (Jalore) and Gigasar (Bikaner). Besides, lectures on Rodent Pest Management were delivered in on campus trainings organized by KVK and one radio talks was delivered on AIR, Jodhpur

i) On/ Off campus training programme on Rodent Pest Management

S.No.	Title of Training	Date	Village	No. of Participants
1.	Rodent management in field and grain storages	26.09.2014	Lunawas Khara	32 farmers
2.	Rodent management in field and grain storages	26.11.2014	Purkhawas	17 farmers
3.	Rodent management in field and grain storages	09.03.2015	Lunawas Khara	20 farmers
ACTIVITY UNDERTAKEN BY COORDINATING UNIT				
1.	Farmers Training on Rodent Control	Jan. 30,2015	Gigasar (Bikaner)	15 farmers

2.	Field based training on 'Rodent Pest Management"	July 27, 2014	Chuchot (Leh)	32 farmers
3.	Exhibition during Kisan Mela and Farmers Innovation Day	September, 24, 2014	CAZRI Campus	550 farmers visited the stall & interacted on Rodent control technologies
4.	Practical demonstrations during farmers visit to the lab	Jan. 27, 2015	Berai, Ghudyala, Aaria, Ketu	22 farmers
5.		Feb. 11, 2015	Budkia, Dechu, Laban	33 farmers
6.		March 11, 2015	Jalali, Lordi, Paldi, Keru	21 farmers
7.	Field training on Rodent Pest Management in Narmada Canal Command areas		Golasan & Silu (Jalore)	15 farmers
			Total No. of beneficiaries	**785.00**

ii) Lecture during on campus training programmes conducted at KVK Jodhpur

S.No	Topic of lecture	Training	Date	Nos of trainee (Male+Female=Total)	Name of resource person
1.	Rodent pest management in crops and fruit plants	Plant protection measures in crops and fruit plants	27.1.2015 to 28.1.2015	24+0=24	Dr. Vipin Chaudhary
2.	Techniques of Rodent pest management	Improved agri. Technologies for arid zone	11.2.2015 to 12.2.2015	33+0=33	Dr. R.S. Tripathi
3.	Rodent management in rabi crops	Plant protection measures in arid crops	10.3.2015 to 11.3.2015	26+0=26	Dr. R.S. Tripathi
4.	Techniques of Rodent pest management	Improved agri Technologies for arid zone	12.3.2015 to 13.3.2015	25+0=25	Dr. Vipin Chaudhary
5.	Rodent pest management in horticultural crops	Arid fruit cultivation	17.3.2015 to18.3.2015	15+0=15	Dr. Vipin Chaudhary

6.	Distribution of rodent pest in different farming system and their management	Integrated farming	20.3.2015 to 21.3.2015	20+0=20	Dr. R.S. Tripathi

iii) Demonstrations conducted on Rodent Control (KVK)

S. No.	Problem/Activity	Technology provided	Village	No. of Demo Con.	Results
1.	Management of Rodent population in grain storages	Use of Bromodilone rodenticide cake in grain storages	Purkhawas	10	Reduced 40% rodent population in grain storages

iv) Anti-rodent campaign (KVK)

S. No.	Campaign	Village	Date	No. of Participants		
				Male	***Female***	***Total***
1.	Rodent control	Lewara Kalan village	21.7.2014	28	0	28
2.	Rodent control	Purkhawas village	5.12.2014	36	5	41

v) Radio Talks

S.No.	Title	Date of Broadcast
1.	सुरक्षित सामूहिक चूहा नियंत्रण	29.5.14

7. TRAINING//SEMINARS/SYMPOSIUMETC

7.1. <u>During 2012-13</u>

i) Training to Scientists and State officials

SN	Nature of Training	Topics	Date
1	21 Days Training on Vertebrate Pest Management at NIPHM, Hyderabad	(i)Integrated management of rodent pests and recent advances, (ii) Biodiversity of rodents in India (iii) Bamboo flowering related rodent out breaks in NEH region and their management. (iv) Planning Process for Rodent Pest Management	June 5-6, 2012

2	Lead Lecture at BHU, Varanasi on the occasion of 150th birth anniversary of Pt Madan Mohan Malviyaji	Management of rodent pests in India	Nov.,2, 2012
3	Training Course on Improved Agricultural Technologies for rabi crops in Arid Region	Rodent control in rabi crops and safe storage of agricultural produce.	Dec 7, 2012
4	21 Days Training on Vertebrate Pest Management at NIPHM, Hyderabad	(i)Rodent biodiversity in India (ii) Rodent Pest Management in arid zones, (iii) Rodent out breaks-analysis with respect to bamboo flowering in NEH region and (iv) Recent advances in Rodent Pest Management	Feb 23 & 27, 2013
5	National Training on Rodent Pest Management for the officials of A.P and Orissa	(i)Recent trends in Integrated Management of Rodent pests in India. (ii) Planning Process for Rodent Pest Management	Feb 20-26,2013

ii) Special trainings on Rodent Management

SN	Nature of Training	Date	No of participants
1	Proofing and other rodent management practices in M. G. Hospital, Jodhpur	June, 2012	15
2	Specialized Training on Rodent Pest Management in Zoo for the officials of Jodhpur Zoo	March 8, 2013	17

iii) Group Meeting/Meetings/Symposium

SN	Nature of Meeting	Date	Venue
1	Expert Committee on Rodent Control (Govt of India)	May,7.2012	CAZRI, Jodhpur
2	Group Meeting of AINP on Rodent Control	January 22-24,2013	Assam Agril University, Guwahati
3	Symposium on *"Managing Stress in Drylands under Climate Change Scenarios"*	Dec. 1-2, 2012	CAZRI, Jodhpur

7.2. <u>During 2013-14</u>

i) Training to Scientists and State officials

SN	Nature of Training	Topics	Delivered By	Date
1	21 Days Training on Vertebrate Pest Management at NIPHM, Hyderabad	(i) Rodent Biodiversity in India (ii) Rodent pest management in arid zone (iii) Rodent out breaks-Analysis with respect to bamboo flowering in Northeastern region (iv)Recent advances in rodent pest management, research gaps and issues	Dr. R. S. Tripathi	February 19-20, 2014

7.3. <u>During 2014-15</u>

i) Training to Scientists and State officials

SN	Nature of Training	Topics	Delivered By	Date
1.	Second Capacity Enhancement Programme on Rodent Control and zoonotic disease management in Chhattisgarh	(i) Rodent problems in Agriculture and Horticulture sectors (ii) Rodent pests of economic importance – their salient features (iii) Chemicals for rodent pest management , their limitations and their safe and judicious use and (iv) Field Practical	Dr R.S. Tripathi	August 1-2, 2014
2.	Third Capacity Enhancement Programme on Rodent Control and zoonotic disease management in Chhattisgarh	(i) Principles of rodent pest management and Rodent pests of major importance (ii) Chemicals for rodent pest management , their limitations and their safe and judicious use (iii) Planning processes and rodent monitoring during anti rodent campaigns and (iv) Field Practicals	Dr R.S. Tripathi	August 3-5, 2014
3.	Rodent Pest Management training to UG Students	Rodent Pest Management in Agricultural crops	Dr. Vipin Chaudhary	October 17,2014
4.	Orientation Course on IPM organized by NCIPM, New Delhi at RARI, Durgapura,	Rodent Pests Management in field and horticultural crops	Dr. R. S. Tripathi	October 17,2014

	Jaipur For SMS (PP) of KVKs of Rajasthan and Gujarat			
5.	Orientation training program for ARS probationers	Activities carried out under AINP on RC	Dr R.S. Tripathi Dr. Vipin Chaudhary	October 31,2014
6.	Training to Railway officials	Rodent problem at railway premises and its mitigation. Field demonstration of Rodent Management techniques for rodent management	Dr R.S. Tripathi Dr. Vipin Chaudhary Sh R.C. Meena & Sh Surjeet Singh	Jan., 24 & 28, 2015
7.	Winter School on Advances in Integrated Pest Management	Integrated Management of rodent pests in Agriculture	Dr R.S. Tripathi	March 13,2015

ii) Meeting

SN	Meeting	Date
1.	Brainstorming Session on Higher vertebrate pests and Launch Meeting of AINP on Vertebrate Pest Management at New Delhi	February 21,2015

8. PARTICIPATED IN SEMINAR/SYMPOSIUM/WORKSHOP

8.1. During 2012-13

SN	Date	Name of seminar, organisers and venue	Name of the participants
1.	November, 7, 2012, New Delhi	BASF Global Interaction Meet	Dr. R. S. Tripathi
2.	December, 1-2,2012, Jodhpur	Symposium on Managing Stress in Drylands under Climate Change Scenarios organized by AZRAI & CAZRI at Jodhpur.	Dr. R. S. Tripathi

8.2. During 2013-14

S. No.	Date	Name of seminar, organisers and venue	Name of the participants
1.	May 25-26, 2013	Group Meeting of AICRP on Biological Control; NBAII, Bangalore	Dr. R. S. Tripathi
2.	July 3, 2013	Workshop on Hot arid Network; CAZRI, Jodhpur	Dr. R. S. Tripathi

3.	July 11-12, 2013	Joint Group Meeting of AINP on Agricultural Acarology and AINP on White Grub & soil Arthropods; Jaipur	Dr. R. S. Tripathi
4.	July 13, 2013	Rajasthan Conclave; DMRC (ICMR) , Jodhpur	Dr. R. S. Tripathi
5.	July19, 2013	Workshop 'Managing Resources for Optimising Land Productivity in Thar Desert; CAZRI, Under SUMAMAD Project; CAZRI, Jodhpur	Dr. R. S. Tripathi
6.	Nov. 21-22, 2013	Workshop on Online Examination, ASRB, New Delhi	Dr. R. S. Tripathi
7.	Dec. 8, 2013	Stepping towards digital Library and Information Management; CAZRI under E-Granth Project; CAZRI, Jodhpur	Dr. Vipin Chaudhary
9.	Jan. 10, 2014	National workshop on "Science, Technology and Intellectual Property Rights: Envisaging the Interfaces; CAZRI, Jodhpur	Dr. R. S. Tripathi and Dr. Vipin Chaudhary
10.	Jan. 19-20, 2014	Conference of VCs of SAUs & Directors of ICAR; Baramati and Pune	Dr. R. S. Tripathi
12.	February, 21-22, 2014	Workshop on Current Scenario of Rodenticides and their future outlook; Food and Agribusiness School, Hyderabad in collaboration with AINP on Rodent Control, CAZRI, Jodhpur and ANGRAU, Hyderabad; at DOR Hyderabad	Dr. R. S. Tripathi and Dr. Vipin Chaudhary

8.3. <u>During 2014-15</u>

S. No.	**Date**	**Name of seminar, organisers and venue**	**Name of the participants**
1.	April 28,2014	Interaction Meeting of VCs, Directors and PCs organized by ICAR at New Delhi	Dr R.S. Tripathi
2.	September 19,2014	Rajasthan Conclave organized by Desert Medical Research Center (ICMR) at Jodhpur	Dr R.S. Tripathi
3.	October 29-30,2014	Workshop on Open access to Agricultural Knowledge for inclusive growth and Development (NAARM, Hyderabad and GFAR-FAO)	Dr R.S. Tripathi

4.	February, 21, 2015	Brainstorming Session on Higher vertebrate pests and Launch Meeting of AINP on Vertebrate Pest Management organized by AINP on VPM (ICAR) at New Delhi	Dr R.S. Tripathi Dr Vipin Chaudhary Sh Surjeet Singh

9. PUBLICATION

9.1. Research articles

Birah, A., Kumar, A. S. and Tripathi, R.S. 2012. Status of rodent damage to coconut in Andaman and Nicobar Islands. *Journal of Plantation Crops* 40(3): 238-242.

Birah, A., Tripathi, R.S. and Mohan Rao, A.M.K. 2012. New report of little Indian field mouse, *Mus booduga* (Gray) from Andaman and Nicobar islands. *Journal of Plantation Crops* 40(2): 149-151.

Birah, A. Zamir Ahmad, S.K., Anantharaj, A., Tripathi, R.S. and Dam Roy, S. 2014. Occurrence of bandicoot rat, *Bandicota bengalensis* in paddy fields of Bay Islands, India. *Ann. Pl. Protec.* 22 (1): 213-14.

Chaudhary, V. And Tripathi, R.S. 2015. Feeding deterrence of defatted Jojoba (*Simmondisa Chiensis*) meal against Indian gerbil, *Tatera indica* (Hardwicke).*Proceedings of National Academy of Sciences, B. Biology*. DOI 10.1007/s40011-015-0633-7.

Idris, M., Tripathi, R.S. and Chaudhary, V. 2012. Breeding and post natal development of the Short tailed mole rat, Nesokia indica, Gray in arid zone. *Ind. J. Pl. Prot*. Vol40(4): 287-292.

Kumawat, M.M., Singh, K.M., Sen, D. and Tripathi. R.S. 2013. Threatened rodent species of Arunachal Pradesh. *Intl. J. Agri. Env & Biotechnology* 6(4):657-668.

Kumawat, MM. Singh, K.M., Tripathi,R.S. Riba, T, Singh, S and Sen,D, 2014. Rodent outbreak in relation to bamboo flowering in north-eastern region of India. *Biological Agriculture and Horticulture: An International Journal for sustainable Production Systems* (Taylor & Francis) London UK (http.// dx.doi.org/10.1080/ 01448765.2014.925828

9.2. Books Edited

Roy, M. M., Burman, U., Praveen- Kumar, Kaul, R.K., Tripathi, R.S., Sharma, S.B. and Gawaria, K. 2012.Abstracts. *Symposium on "Managing Stress in Drylands under Climate Change Scenarios".* Published by Arid Zone Research Association of India, Jodhpur (December 1-2, 2012). 327p.

9.3. Book Chapter

Singh, P. and Tripathi, R.S. and Sharma, B.K. 2013. Non-volant small mammals of Rajasthan. *In: Faunal Heritage of Rajasthan, India: General Background and Ecology of Vertebrates*, Vol 1 (Eds: Sharma, B.K., Kulshrestha, S. and Rahmani, A.R) Springer, New York. Pp 549-561.

Tripathi,R.S and Tomar, A.S. 2013. *Fasalon Me Chuha Niyantran.* Shusak Chhetra Me Krishi Ki Unanat Taknikiyan. KVK, CAZRI, Jodhpur. pp 86-88.

Tripathi, R.S. 2014. Integrated Management of Rodent Pests. In Integrated Pest Management-Current Concepts and Ecological Perspective (Eds. Abrol, D.P.) Elsevier Inc. 419-459.

Tripathi, R.S. 2014. Integrated Management of Rodent Pests.In *Integrated Pest Management-Current Concepts and Ecological Perspective* (Eds. Abrol, D.P.) Elsevier Inc. 419-459.

9.4. Popular Articles

Birah, A., Ahmad, Z., and **Tripathi, R.S.** 2013. *Dhan ki fasal mein Chooha Niyantran. Kheti.* September 2013: 32.

9.5. Papers in Symposia/Seminars/Conferences

Birah Ajanta, Anantharaj A. and Tripathi R. S. 2012. Rodent Diversity of Andaman and Nicobar Islands. *SovenierNational Seminar on Innovative technologies for Conservation and Sustainable Utilization of Island Biodiversity*, December 20-22, 2012, Port Blair, p52-56.

Chaudhary, V. 2014. Current status of rodenticides in India - scope for further development. *Proceed. Workshop on "Current Scenario of Rodenticides and their future outlook;* Food and Agribusiness School, Hyderabad in collaboration with AINP on Rodent Control, CAZRI, Jodhpur and ANGRAU, Hyderabad; at DOR Hyderabad (Feb 21-22,2014).

Chaudhary, V. And Tripathi, R.S. 2015. Managing rodents using anticoagulant rodenticides. *In Souvenir and abstract book of National Entomologists' Meet.* Eds. Sharma, K.K., Monobrullah, Md., Mohanasundaram, A. And Ramani, R. Publisher Soc. for Advancement of Natural Resins and Gums. Pp.58-59.

Meena, R.C., Singh, S. and Tripathi, R.S.2012, Single dose efficacy of brodifacoum (0.005%0 against commensal rodents. *Symposium on Managing Stress in Drylands under Climate Change Scenarios* (Dec1-2,2012) AZRAI & CAZRI, Jodhpur. p. 102-03.

Singh, B. and Tripathi, R.S. 2012 Popularization of pest and disease management technologies in adopted village of Jodhpur District of Rajasthan. *Symposium on Managing Stress in Drylands under Climate Change Scenarios* (Dec1-2,2012) AZRAI & CAZRI, Jodhpur. pp. 297-98.

Singh, P, Arora, A. Tripathi, R.S. and Solanki, J, 2012. Changing ecology of Thar desert and its implications on biological recourses. *Symposium on Managing Stress in Drylands under Climate Change Scenarios* (Dec1-2,2012) AZRAI & CAZRI, Jodhpur. p. 33.

Tripathi, R.S and Narsimha Rao, C.V. 2013. Recent trends in Rodent pest management. In *National Training on Rodent Pest Management.* Held at ANGRAU, APRRI, Maruteru (Feb 20-26,2013) pp 46-53.

Tripathi, R.S. 2012.Rodentia (Class: Mammalia): Faunistic Diversity in North-western arid regions of India. ProccedXXIII National Symposium on Chronobiology and Seminar on Diversity and Physiology of Desert Fauna to be held at Jodhpur (March 1-3, 2012), Abs. pp 57-58.

Tripathi, R.S. 2014. Rodents as pests with respect to food security, *Proceed. Workshop on "Current Scenario of Rodenticides and their future outlook;* Food and Agribusiness School, Hyderabad in collaboration with AINP on Rodent Control, CAZRI, Jodhpur and ANGRAU, Hyderabad; at DOR Hyderabad (Feb 21-22,2014).

Tripathi, R.S. 2014. Role of antifertlity agents in rodent pest management. *Proceed. Workshop on "Current Scenario of Rodenticides and their future outlook;* Food and Agribusiness School, Hyderabad in collaboration with AINP on Rodent Control, CAZRI, Jodhpur and ANGRAU, Hyderabad; at DOR Hyderabad (Feb 21-22,2014).

9.6. <u>Monographs/ Technical Bulletins/Mannuals/Reports/Extension Folders etc.</u>

Bora, D.K., Borah, R.K. and Tripathi, R.S. 2013. Rodents and their Management in rice crop fields and house holds. AINPP on Rodent Control, AAU, Jorhat. 4p.

Chakravarthy, A.K, Shivayya,V., Tripathi, R. S. and Girish, A. C. 2013. Porcupine: the Robust Rodent. Tech. Bulletin No 18. AINP on Rodent Control, Central Arid Zone Research Institute, Jodhpur. 39 p.

Chakravarthy,A.K, Shivayya,V., Tripathi, R. S. and Girish, A. C. 2012. Porcupine: the Robust Rodent. Tech. Bulletin No 18. AINP on Rodent Control, Central Arid Zone Research Institute, Jodhpur. 39 p.

Singh, B., Tripathi, R.S., Singh, Raj, Lodha, S.K. and Bohra, H.C. 2014. *Shusk Kshetra mein CAZRI ki Unnat taknikiyon ka hastantaran Evam Prabhav*. CAZRI, Jodhpur 26p.

Singla,N, Kochar, D.K, Kaur, R, Parshad, V.R., Babbar, B.K. and Tripathi, R.S. 2012. Recent Advances in Rodent Research in Punjab. Occasional paper No 1. AINP on Rodent Control, Central Arid Zone Research Institute, Jodhpur. 56 p.

Singla,N, Kochar, D.K, Kaur, R, Parshad, V.R., Babbar, B.K. and Tripathi, R.S. 2013. Recent Advances in Rodent Research in Punjab. Occasional paper No 1. AINP on Rodent Control, Central Arid Zone Research Institute, Jodhpur. 56 p.

Tripathi, R.S, Chaudhary, V.and Tomar, A.S. 2013. *Rabi Fasalon Me Chuha Niyantran*. *In* Training Manual Rabi Fasalon Ki Unanat Taknikiyan Per Prashikshan 17-21 Dec, 2013 at KVK, Jodhpur. Pp 66-69.

Tripathi,R,S and Singh, B.2012. *Shushk Kshetron ki fasalon mein Chooha Niyantran*, Central Arid Zone Research Institute, Jodhpur. 6 p.

9.7. Rodent Newsletter Vol 36 (1-4) 2012, Vol 37 (1-2) 2013, Vol 37 (3-4) 2013 was published

Network Coordinating Unit (Rodent Control)
CAZRI, Jodhpur
Actual expenditure for the FY 2012-13 to 2014-15
(ICAR Share only)

(Rs. in lakhs)

Head/ Year	2012-13	2013-14	2014-15	Total
Pay & Allowances	0.00	0.00	0.00	**0.00**
T.A.	1.37	2.20	3.49	**7.06**
Rec. Contingencies	3.08	2.74	9.50	**15.32**
NRC	0.00	0.00	0.00	**0.00**
Total	**4.45**	**4.94**	**12.99**	**22.38**

PUNJAB AGRICULTURAL UNIVERSITY, LUDHIANA –141004

PART I: GENERAL INFORMATION

1. Name of the centre	Punjab Agricultural University, Ludhiana Department of Zoology
2. Sanction no.	1-2/77-pp dated 2.7.1977 and 7-1/85pp dated 29.10.1988
3. Date of start	20.1.1978
4. Date of Termination	Network Project of continued nature
5. Report period	2012-13 to 2014-15
6. Scientist Incharge	**Dr. Neena Singla**

7. Staff Position

Sr. No.	Name of post	No. of posts sanctioned	Name of incumbent	Date of Joining	Date of Leaving
I.	Zoologist (Rodents)	1	1. **Dr. Neena Singla** Zoologist (Rodents) Rs.37400-67000+9000 GP	28.07.2000	Continued
II.	Assistant Zoologist (Rodents)	3	1. **Dr. Bhupinder Kaur** Assistant Zoologist Sr. scale (Rodents) Rs.15600-39100+7000 GP	28.12.2005	Continued
			2. **Dr. Rajwinder Singh** Assistant Zoologist (Rodents) Rs. 15600-39100 + 6000 GP	01.06.2012	Continued
			3. **Dr Navdeep Kaur** Assistant Zoologist (Rodents) Rs. 15600-39100 + 6000 GP	11.11.2013	Continued
III	Senior Scale stenographer	1	**1. Mr. Davinder Kumar**	07.08.2012	Continued

			Rs. 10300-34800+4400 GP + 480 SP		
IV	Agricultural Sub Inspectors	3	1.**Mr. Major Singh** Rs. 10300-34800+4350 GP 2.**Ms. Baljit Kaur** Rs. 10300-34800+3600 GP 3.**Mr. Ram Parshad** Rs10300-34800+3200 GP	31.10.1989 22.09.2012 01.03.2013	Retd on 30.06.2014 Continued Continued
V	Driver	1	1**. Mr. Husan Kumar** Rs. 5910-20200 + 2000 GP + 1400 SA + 700 SP	15.03.2012	08.01.2015

PART II: WORK ALLOTTED

RM–1. Surveillance of pest rodents in Rice-wheat-sugarcane cropping system of Punjab.

RM–2. Monitoring of rodent abundance and damage in Northestern zone of Punjab.

RM–3. Evaluation of botanicals against rodent for antifeedant /deterrent/ attractant effects

RM–4. Evaluation of chemical compounds for toxic and anti-fertility properties for data generation on Indian rodents.

RM-5. Development of rodent management technologies under storage conditions.

RM–6. Bio-ecology of *Tatera indica.*

RM-7. Development/ Refinement of rodent pest management modules in predominant crops/cropping systems.

RM-8. Social engineering activity on rodent pest management as participatory adaptive research in adopted villages.

RM–9. Studies on predatory potential of barn owls and its utilization for bio-control of rodent pests.

RM–10. Studies on zoonosis in relation to rodent population outbreak and crop harvest seasons.

Location Specific:

(a) Toxicology of existing rodenticides

(b) Studies on development of ready to use bait of acute rodenticides.

(c) Behavioural studies on predominant rodent species.

(d) Evaluation of triptolide for antifertility effects against predominant rodents

(e) Studies on potential of parasites/ predatory cues for bio control of rodent pests.

PART III: WORK DONE

1. SURVEILLANCE OF PEST RODENTS IN RICE-WHEAT-SUGARCANE CROPPING SYSTEM OF PUNJAB

Surveillance of pest rodents in rice-wheat cropping system with vegetables, pulses, sugarcane and maize as minor crops at monthly intervals revealed the predominance of *Bandicota bengalensis* followed by *Tatera indica, Millardia meltada* and *Mus booduga*. The trapping of female rats was more than that of male rats. Trapping of *B. bengalensis* was more in months of June-July, October-November and January-February, whereas that of *T. indica* was more in months of June and November to January. *M. meltada* was trapped more in the months of June, August-September and November-December. Maximum damage was reported in pumpkin (14.66%) and bottle gourd (12-27%) crops in the months of July-August. Large complexes of *B. bengalensis* were found in these fields.

Trapping in the month of January, 2014 in kandi area of district Hoshiarpur, Punjab revealed the presence of *Nesokia indica, T. indica* and *M. booduga*. Large burrow complexes of *N. indica* with heaps of loose soil near the burrow openings were found in wheat crop. Trapping from fish market near Sidhwan canal, restaurants and shopping complex areas in Ludhiana revealed the existence of *B. bengalensis* thus indicating the commensalization of *B. bengalensis* in these areas. Trapping from different poultry farms in and around Ludhiana revealed the predominance of *Rattus rattus*.

2. MONITORING OF RODENT ABUNDANCE AND DAMAGE IN NORTHEASTERN ZONE OF PUNJAB

2.1. <u>Pre-harvest rodent damage in crop fields</u>

A survey of rodent damage to wheat, rice, basmati and cotton crops at pre-harvest stage was conducted in villages of eight districts namely Hoshiarpur, Ferozepur, Roop Nagar, Amritsar, Gurdaspur, Bathinda, Mohali and Tarn Taran revealed 0.67 to 3.89% cut tillers in wheat crop, 0.27 to 1.74% cut tillers in rice crop, 0.15 to 0.25% cut tillers in basmati crop and no damage

to cotton crop. Yield loss (kg/ha) ranged from 79.68 to 241.94 in wheat crop, 20.07 to 186.29 in rice crop, 15.55 to 20.00 in basmati crop and nil in cotton crop (Table 1).

Table 1. Pre-harvest rodent damage in crop fields

Period	Crop	District	Cut tillers (%)	Yield loss (Kg/ha)
Oct, 12	Rice	Hoshiarpur	0.27±0.04	20.07±2.06
		Ferozepur	0.81±0.05	83.70±3.64
Oct, 12	Basmati	Hoshiarpur	0.25±0.03	15.55±0.61
		Ferozepur	0.15±0.06	20.00±8.17
Apr, 13	Wheat	Roop Nagar	0.67±0.36	79.68±35.73
		Amritsar	1.49±0.62	82.77±31.29
		Gurdaspur	3.89±2.02	241.94±117.24
Oct, 13	Rice	Roop Nagar	1.74±0.07	186.29±24.92
		Amritsar	0.92±0.28	84.27±22.07
		Gurdaspur	0.98±0.03	104.63±16.04
		Bathinda	0.96±0.07	85.29±0.72
Oct, 13	Cotton	Bathinda	0.00±0.00	0.00±0.00
Apr, 14	Wheat	Mohali	1.79±0.42	179.56±46.14
		Tarn Taran	1.85±0.18	136.56±14.10
Oct, 14	Rice	Mohali	0.50±0.20	41.91±13.20
		Tarn Taran	0.95±0.58	79.79±9.49

Values are Mean ± SE

2.2. Post-harvest burrow count in crop fields

Burrow count of different rodent species on the basis of characteristic burrow entrances after harvest was recorded in wheat, rice, basmati and cotton crops after harvesting in villages of eight districts namely Hoshiarpur, Ferozepur, Roop Nagar, Amritsar, Gurdaspur, Bathinda, Mohali and Tarn Taran. Data revealed the predominance of *B. bengalensis* followed by *M. booduga*, *M. meltada* and *T. indica* with burrows ranging from 0.67 to 25.11, 1.33 to 15.77, 0.56 to 4.00 and 0.33 to 1.22 per 0.4 ha, respectively (Table 2).

Table 2. Post-harvest burrow count in crop fields

Period	Crop	District	No. of rodent burrows / 0.4 ha (Mean ± SE)				
			Bb	**Mb**	**Ti**	**Mm**	**Total**
Oct, 12	Rice	Hoshiarpur	5.03±0.43	7.44±3.53	1.00±0.82	3.89±1.20	17.36±5.86
		Ferozepur	3.66±0.24	2.33±0.24	-	-	6.00±0.00
Oct, 12	Basmati	Hoshiarpur	7.66±1.65	11.83±8.37	0.50±0.35	4.00±1.92	24.00±3.07
		Ferozepur	0.67±0.27	1.33±0.72	-	-	2.00±0.49
Apr, 13	Wheat	Roop Nagar	2.44±0.95	1.45±0.50	-	-	3.89±1.05
		Amritsar	25.11±3.54	15.77±0.71	1.22±0.48	-	42.11±4.39
		Gurdaspur	16.64±3.76	5.44±0.63	0.55±0.24	-	22.66±3.96
Oct, 13	Rice	Roop Nagar	-	-	-	-	33.22±3.09
		Amritsar	-	-	-	-	21.33±3.14
		Gurdaspur	-	-	-	-	23.11±2.38
		Bathinda	12.55±0.33	9.00±0.41	0.33±0.27	-	21.89±0.95
Oct, 13	Cotton	Bathinda	12.11±1.27	9.72±0.52	0.55±0.45	-	22.39±0.51
Apr, 14	Wheat	Mohali	6.22±1.35	-	-	-	6.22±1.35
		Tarn Taran	18.44±1.49	6.11±0.40	-	-	24.55±1.31
Oct, 14	Rice	Mohali	14.00±5.03	2.89±1.55	-	0.56±0.45	42.11±4.39
		Tarn Taran	6.89±0.39	3.78±0.50	-	-	10.67±1.73

Bb: *B. bengalensis*, Mm: *M. booduga*, Ti: *T. indica*, Mm: *M. meltada*

2.3. Rodent damage in vegetable crops

Different vegetable crops were surveyed for rodent damage at Ladhowal Seed Farm of PAU, Ludhiana from April to July, 2014. *B. bengalensis* was the predominant species in all the crops. Rodent damage was maximum in the month of May in summer squash and tomato crops and in July in muskmelon crop which may be due to increase in sweetness in fruits during this period. In okra and green chilly crops, no rodent damage was recorded.

3. EVALUATION OF BOTANICALS AGAINST RODENT PESTS FOR ANTIFEEDANT/DETERRENT/ ATTRACTANT EFFECTS

3.1. Antifeedant/repellent effects of Trans-Anethole against *R. rattus* and *B. bengalensis*:

The bioactivity of *Trans*-Anethole, essential oil of bitter fennel fruits was observed in bi-choice feeding test against two species i.e. *B. bengalensis* and *R. rattus* at 3% concentration in bait. The data revealed that the compound has antifeedant effect against both the rodent species, as shown by increased per cent antifeedant index. The antifeedant index ranged from 46.3 to 76.8% against B. *bengalensis* and 48.6 to 75.3% against *R. rattus* from day 1 to day 4. So *trans*-Anethole can be further evaluated and used for integration with other methods of rodent control.

3.2. Antifeedant/repellent effect of cinnamamide against *R. rattus*

Different groups of mature and healthy *R. rattus* were exposed to three different concentrations of cinnamamide (0.2, 0.3, and 0.4%) in bi-choice feeding tests for three consecutive days during treatment period 1. Treatments were repeated again after 7 days of treatment period 1 (treatment period 2) and after 14 days of treatment period 2 (treatment period 3) to test whether rats retain the memory of compounds after 7 and 14 days of treatment. Hourly consumption of rats treated with effective doses of cinnamamide (0.4%) up to 4 hours under no-choice and bi-choice conditions was also recorded to confirm the existence of primary repellent effect of both the chemicals. Results of treatment period 1 revealed significant difference in food consumption between the two sexes. In both the sexes, the consumption of bait treated with 0.4% cinnamamide was significantly low. At 0.4% concentration, percent antifeedant index was found to be 46.87 in male rats and 52.42 in female rats (Table 3). During treatment period 2 and 3 also, 0.4% cinnamamide treated bait proved to be effective as antifeedant or with secondary repellent. Animals were not habituated to effective dose of cinnamamide. So this dose of cinnamamide can be utilized as a non-lethal management tool for inhibiting rats from sampling and gnawing food in store houses.

There was no significant difference between consumption of treated and untreated bait during first four hours after exposure of rats to the effective dose of cinnamamide under both no-choice and bi-choice feeding tests (Table 4). Rats showed no repellency towards treated bait during first few hours of their exposure to treated bait indicating absence of primary or gustatory/olfactory repellent effect in house rats toward effective dose of cinnamamide.

Table 3. Antifeedant index of bait treated with cinnamamide against *R. rattus* during different treatment periods

Sex* (n=5)	Conc. tested	Antifeedant index (%) Mean±SE		
		I treatment period	II treatment period (7 days)	III treatment period (after 14 days)
Male	0.2%	nil	nil	nil
	0.3%	nil	nil	nil
	0.4%	46.87±10.75	59.44±8.59	44.34±8.19
Female	0.2%	nil	nil	nil
	0.3%	nil	nil	nil
	0.4%	52.42±5.30	46.26±11.90	49.80±8.12

** Significant difference in food consumption between the two sexes*

Table 4. Hourly consumption of plain and treated bait (0.4% cinnamamide) in no-choice and bi-choice feeding tests

Feeding test	Time	Male* (Mean ± SE)		Female* (Mean ± SE)	
		Plain[1]	Treated[1]	Plain[1]	Treated[1]
No-choice	1st hr	0.24±0.02[a]	0.14±0.00[a]	0.16±0.11[b]	0.24±0.01[b]
	2nd hr	0.12±0.01[a]	0.13±0.00[a]	0.22±0.01[b]	0.14±0.02[b]
	3rd hr	0.24±0.07[a]	0.28±0.12[a]	0.17±0.04[b]	0.18±0.06[b]
	4th hr	0.18±0.05[a]	0.23±0.00[a]	0.27±0.05[b]	0.23±0.03[b]
Bi-choice	1st hr	0.19±0.04[a]	0.14±0.04[a]	0.16±0.11[b]	0.13±0.01[b]
	2nd hr	0.17±0.03[a]	0.15±0.04[a]	0.14±0.01[b]	0.17±0.02[b]
	3rd hr	0.17±0.04[a]	0.15±0.14[a]	0.16±0.04[b]	0.15±0.06[b]
	4th hr	0.20±0.04[a]	0.14±0.05[a]	0.17±0.05[b]	0.13±0.03[b]

** No significant difference in overall hourly consumption of treated bait between the two sexes*
[1] No significant difference in overall average consumption of plain and treated bait
[a, b] show no significant difference in mean consumption of plain and treated baits from 1-4 hour period in male and female rats

3.3. Antifeedant/repellent effect of cinnamic aldehyde against *R. rattus*

Exposure of *R. rattus* of both sexes to bait containing 1, 2.5 & 5% cinnamic aldehyde for 3 days in bi-choice feeding test and then again after a gap of 7 and 15 revealed reduced consumption of all concentrations of treated bait as compared to plain bait in both sexes during first, second (7 days after first treatment) and third treatment (15 days after second treatment) period indicating antifeedant effect of all concentrations of cinnamic aldehyde against *R. rattus* (Table 5). This antifeedant effect was retained in the memory of rats even after 7 and 21 days of the start of experiment although it reduced during second and third treatment period as compared to first treatment period. Out of the three concentrations of cinnamic aldehyde tested, antifeedant effect was more with 5% concentration in both sexes.

Table 5. Antifeedant index of bait treated with cinnamic aldehyde against *R. rattus* during different treatment periods

Sex* (n=5)	Conc. tested	Antifeedant index (%) Mean±SE		
		First treatment period	Second treatment period (after 7 days)	Third treatment period (after 15 days)
Male	1%	68.42±7.95	65.38±9.80	58.17±7.63
	2.5%	79.94±5.291	53.45±10.29	66.51±7.82
	5%	85.94±5.48	55.13±6.96	57.16±14.99
Female	1%	56.69±7.00	34.46±10.15	33.50±7.47
	2.5%	41.60±8.44	43.07±13.19	40.62±13.70
	5%	72.82±10.63	50.6±8.01	54.79±8.89

*Significant difference in food consumption between the two sexes

There was no significant difference between consumption of treated and untreated bait during first four hours after exposure of rats of both sexes to effective dose of cinnamic aldehyde under both no-choice and bi-choice feeding tests (Table 6). Rats showed no repellency towards treated bait during first few hours of their exposure to treated bait indicating absence of primary or gustatory/olfactory repellent effect in house rats toward effective dose of cinnamic aldehyde.

Table 6. Hourly consumption of plain and treated bait (5% cinnamic aldehyde) in no-choice and bi-choice feeding tests

Feeding test	Time	Male* (Mean ± SE)		Female* (Mean ± SE)	
		Plain[1]	Treated[1]	Plain[1]	Treated[1]
No-choice	**1st hr**	0.13±0.07[a]	0.10±0.04[a]	0.16±0.04[b]	0.05±0.00[b]
	2nd hr	0.00±0.00[a]	0.02±0.00[a]	0.12±0.06[b]	0.02±0.01[b]
	3rd hr	0.12±0.04[a]	0.03±0.01[a]	0.28±0.12[b]	0.19±0.12[b]
	4th hr	0[a]	0.03±0.02[a]	0.01±0.00[b]	0.04±0.02[b]
Bi-choice	**1st hr**	0.04±0.02[a]	0.04±0.00[a]	0.06±0.11[b]	0.04±0.01[b]
	2nd hr	0.02±0.01[a]	0.03±0.00[a]	0.02±0.01[b]	0.04±0.02[b]
	3rd hr	0.14±0.07[a]	0.18±0.12[a]	0.17±0.04[b]	0.12±0.06[b]
	4th hr	0.08±0.05[a]	0.03±0.00[a]	0.07±0.05[b]	0.03±0.03[b]

* No significant difference in overall hourly consumption of treated bait between the two sexes

[1] No significant difference in overall average consumption of plain and treated bait

[a, b] show no significant difference in mean consumption of plain and treated baits from 1-4 hour period in male and female rats

The antifeedant or secondary repellent effect of effective dose of cinnamic aldehyde (5%) is more in bi-choice feeding test and retained for experimental period of 27 days when there is availability of another source of food (Table 7). Animals were not habituated to effective dose of cinnamic aldehyde. So 5% cinnamic aldehyde can be used under field conditions to prevent the damage caused by house rats under commensal situations.

3.4. Antifeedant/repellent effect of cinnamic aldehyde against *B. bengalensis*

Four different concentrations of cinnamic aldehyde (1, 2.5, 5, and 7.5%) were tested against *B. bengalensis* in bi-choice feeding tests. Results revealed maximum antifeedant/secondary repellent effect of 5% cinnamic aldehyde treated bait which was retained both at a gap of 7 and 14 days of treatment (Table 8). There was a non-significant difference between average consumption of untreated and treated bait during first two hours indicating absence of primary repellent effect of cinnamic aldehyde in both the sexes (Table 9). Rats were not habituated to effective concentration of cinnamic aldehyde upto experimental period of 27 days (Table 10). Different formulations were prepared using 5% cinnamic aldehyde and tested on field crops by treating the seeds and by spraying. Formulation II containing 5% cinnamic aldehyde, 1% sodium bicarbonate as emulsifier and 1% tert-butyl hydroxyquionone as photo-stabilizer

prevented rodent damage upto 14 days in summer squash, 12 days in tomato and also reduces the damage in black mash upto 16 days indicating that photostabilizer present in formulation prevented photo degradation of cinnamic aldehyde and thus increased effectiveness of cinnamic aldehyde to prevent rodent attack to field crops. Formulations I and (III-X) could not prevent the damage caused by the rodents.

Table 7. Antifeedant index and consumption of bait treated with 5% cinnamic aldehyde for 27 days in bi-choice feeding tests

Days	Consumption (g/100g bw) of bait		Antifeedant index (%)
	Plain	Treated	
1-3	5.96±0.54[a]	0.76±0.19[b]	77.12±5.26
4-6	5.94±0.44[a]	0.37±0.09[b]	86.90±1.50
7-9	7.70±0.75[a]	1.90±0.50[b]	65.40±4.87
10-12	6.79±0.54[a]	1.85±0.57[b]	64.20±2.52
13-15	6.82±0.48[a]	1.50±.40[b]	67.34±2.18
16-18	8.05±0.44[a]	1.16±0.38[b]	77.16±5.20
19-21	8.02±1.36[a]	1.74±0.40[b]	66.27±10.52
22-24	8.22±0.66[a]	0.90±.50[b]	84.80±10.74
25-27	6.80±0.94[a]	0.66±0.20[b]	84.96±5.57

Values are Mean ± SE, [a, b S]ignificant difference in consumption of plain and treated bait along the columns as well as in rows.

Table 8. Antifeedant of bait treated with different concentrations of cinnamic aldehyde during three treatment periods

Sex* (n=5)	Conc. tested	Antifeedant index (%) Mean±SE		
		First treatment period	Second treatment period (after gap of 7 days)	Third treatment period (after gap of 14 days)
Male	1%	69.90±3.90	59.40±2.9	59.4±2.9
	2.5%	63.20±5.80	55.80±7.82	55.8±7.82
	5%	79.06±2.60	70.20±6.10	70.20±6.10

	7.5%	73.20±5.70	79.60±2.40	79.60±2.40
Female	1%	60.90±5.50	73.50±4.31	73.50±4.31
	2.5%	82.90±0.90	75.20±3.39	75.20±3.39
	5%	87.20±4.80	84.50±5.17	84.50±5.17
	7.5%	73.50±4.31	84.80±1.90	84.80±1.90

*Significant difference in antifeedant index between the two sexes

Table 9. Hourly consumption of plain and treated bait (5% cinnamic aldehyde) in bi-choice feeding test

Hours of treatment	Consumption of bait (g/100g bw) Mean ± SE			
	Male* (n=5)		Female* (n=5)	
	Plain	Treated	Plain	Treated
1st hr	1.24±0.15[1]	0.73±0.06[1]	0.62±0.03[ab]	0.48±0.11[ac]
2nd hr	0.39±0.14[2]	0.13±0.17 [23]	0.26±0.14 [a]	0±0 [ac]
3rd hr	0.63±0.04[2]	0±0 [3]	1.09±0.09 [b]	0±0 [c]
4th hr	0.23±0.12[2]	0.1±0.08[23]	0.48±0.11 [a]	0.23±0.12 [a c]
5th hr	0.10±0.08[2]	0±0[23]	0.73±0.18 [ab]	0±0 [c]
6th hr	0.33±0.12[2]	0±0[23]	0.62±0.03 [ab]	0±0 [c]
Mean	1.07±0.47	0.04±0.04	1.15±0.59	0.16±0.05

** Significant difference in overall hourly consumption between the two sexes*

[1,2] shows significant difference in consumption of plain and treated baits along the rows in male rats; ; [a,b] shows significant difference in consumption of plain and treated baits along the rows in female rats

Table 10. Antifeedant index and consumption of plain and treated bait (5% cinnamic aldehyde) for 27 days in bi-choice feeding tests

Male# (Mean ± SE)				Female# (Mean ± SE)		
Days	Consumption (g/100g bw) of bait		Antifeedant index (%)	Consumption (g/100g bw) of bait		Antifeedant index (%)
	Plain*	Treated*		Plain*	Treated*	
1-3	8.90±0.42	1.28±0.09	74.78±0.96	7.78±0.39	1.39±0.10	69.72±1.18
4-6	9.28±0.79	0.95±0.16	82.18±3.30	8.12±0.70	1.22±0.20	74.3 ±2.12

7-9	8.74±0.38	1.16±0.14	76.88±3.5	7.82±0.24	1.18±0.12	72.4±2.91
10-12	9.03±0.29	1.01±0.05	79.97±1.97	8.42±0.35	1.03±0.20	78.4 ±3.57
13-15	8.27 ±0.41	1.04±0.13	77.78±2.51	7.46±0.31	1.17±0.13	73.1±2.31
16-18	9.39±0.80	0.97±0.14	80.6±3.17	8.64±0.46	1.16±0.09	76.2±1.58
19-21	8.63±0.34	1.28±0.09	74.08±1.35	8.28±0.27	1.42±0.05	70.6±1.04
22-24	8.63 ±0.50	1.02±0.15	78.99±2.59	8.14±0.55	1.21±0.11	73.8±2.48
25-27	9.16±0.73	1.07±0.10	78.89±1.45	8.52±0.47	1.21±0.11	75.07±2.01

[#] *Significant difference in overall hourly consumption between the two sexes*

[*] *Significant difference in consumption of plain and treated bait between the two sexes*

3.5. Antifeedant/repellent effect of eucalyptus oil against *R. rattus*

Three different concentrations of eucalyptus oil i.e. 5, 10 and 20% were tested against *R. rattus* in laboratory pens. For each concentration of the oil, three methods of application i.e. paint (applied by using cotton swab dipped in oil), spray (applied by a small spray pump of 100 ml capacity), and wax blocks encapsulating 3 drops of a particular concentration of oil were tested. In each experiment, rats were exposed to the treatment for 3 weeks using different mode of application/treatment in each week i.e. oil applied daily, oil applied once a week and oil applied alternatively. The effect of treatment was recorded after 24 h of treatment for 4 days in a week i.e. from Tuesday to Friday. Each pen consisted of three chambers of equal size. One rat was released in each chamber. Each chamber on its opposite facing sides was connected with holes to two small nest boxes. Rats had free access to these nest boxes. Treatment was carried out in the nest box of one side of each chamber. Weighed amount of food taken in a bowl was placed in both the nest boxes of each chamber. Repellent effect of the oil was assessed based on the consumption of food by the rat from the food bowls kept in two nest boxes of a chamber in a laboratory pen. Results revealed a significantly low consumption of bait from treatment side compared to untreated side at all the modes of application under each method of application (Tables 11-13).

In overall, a significant difference in the effect of treatment was observed between the two sexes with higher repellent effect in female rats as compared to male rats. There was no significant difference in repellent effects of oil between 5 and 10% and between 10 and 20% concentrations of the oil. A significant difference was, however, observed between 5 and 20% concentrations with higher repellent effect of oil at 20% concentration followed by 10 and 5%. A significant difference in the three methods of application was also observed with higher effect when the oil was used as spray followed by when it was used as encapsulated wax blocks and as paint. A significant difference in repellent effects when the oil was applied alternatively was observed with that observed when the oil was applied daily and once a week. There was no significant difference observed in four days of treatment. Food consumption was

significantly low from treatment side of the chamber of the laboratory pen as compared to that observed from untreated side.

3.6. Antifeedant/repellent effect of citronella oil against *R. rattus*

Experiments conducted in laboratory pens by using three concentrations of citronella oil i.e. 5, 10 and 20%, each as paint, as encapsulated wax blocks and as spray and each further with three modes of application i.e. daily, once a week and alternatively revealed significantly low consumption of bait from treatment side compared to untreated side at all the modes of application under each method of application (Tables 14-16). In overall, a significant difference in the effect of treatment was observed between the two sexes with higher repellent effect in male rats as compared to female rats. A significant difference was observed between concentrations 5 and 10% and between 5 and 20% of citronella oil with higher repellent effect of oil at 10% concentration followed by 20 and 5%. A significant difference was also observed among the three methods of application with higher repellent effect of the oil when applied as spray followed by that when applied as encapsulated blocks and as paint. No significant difference was observed among the three modes of application.

Table 11. Percent repellency with 5% eucalyptus oil when applied using three different methods against *Rattus rattus*

Mode of application	Days of application	Percent repellency					
		Paint		Block		Spray	
		Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)
I	Day 1	47.54±22.82 [a]	91.15±8.70 [b]	46.16±35.76 [a]	82.43±16.19 [b]	84.47±28.14 [a]	82.98±20.55 [a]
	Day 2	43.29±35.84 [a]	91.03±13.64 [b]	32.03±31.94 [a]	56.91±23.36 [ab]	88.02±9.91 [a]	75.36±21.92 [a]
	Day 3	43.36±41.70 [a]	90.75±16.11 [b]	48.49±36.68 [a]	60.71±27.26 [ab]	76.13±37.52 [a]	54.38±46.45 [a]
	Day 4	78.30±20.81 [a]	28.34±35.19 [c]	64.70±20.95 [a]	55.18±35.01 [ab]	86.12±21.12 [a]	88.47±26.69 [a]
	Average	**53.12±14.63 [A]**	**75.31±27.12 [A]**	**47.84±11.59 [A]**	**63.80±10.93 [A]**	**83.68±4.53 [A]**	**75.29±12.94 [A]**
II	Day 1	63.16±44.80 [a]	92.78±8.48 [a]	34.62±25.28 [a]	64.53±23.82 [b]	56.48±42.51 [a]	78.27±26.69 [a]
	Day 2	53.27±39.57 [a]	58.24±44.89 [ab]	23.92±18.40 [a]	52.79±33.30 [ab]	56.56±37.17 [a]	54.15±38.84 [a]
	Day 3	35.98±35.64 [ab]	18.89±30.42 [b]	6.04±13.36 [a]	38.81±37.69 [ab]	60.68±43.23 [a]	61.35±41.87 [a]
	Day 4	24.65±34.87 [ab]	27.67±40.34 [b]	42.60±27.65 [a]	45.17±26.21 [ab]	47.54±41.32 [a]	38.58±38.89 [a]
	Average	**44.26±14.92 [AB]**	**49.39±28.99 [B]**	**26.79±13.69 [B]**	**50.32±9.57 [A]**	**55.31±4.79 [B]**	**58.08±14.26 [B]**
III	Day 1	43.32±32.44 [a]	42.49±39.03 [a]	31.66±22.51 [a]	81.58±16.88 [b]	42.31±22.28 [a]	36.58±24.41 [a]
	Day 2	47.32±19.63 [a]	33.67±37.79 [a]	23.92±18.40 [a]	52.36±28.74 [c]	72.80±34.33 [a]	60.79±21.30 [a]
	Day 3	45.47±27.25 [a]	33.33±47.14 [a]	6.04±13.36 [ac]	28.08±27.08 [c]	57.04±42.37 [a]	43.07±45.24 [a]
	Day 4	64.10±28.79 [a]	48.71±43.89 [a]	41.60±27.54 [ab]	70.79±31.55 [b]	70.21±33.99 [a]	57.77±30.93 [a]
	Average	**50.05±8.23 [AB]**	**39.55±6.43 [B]**	**25.80±13.01 [B]**	**58.20±20.28 [A]**	**60.59±12.12 [B]**	**49.55±10.05 [B]**

- *Values are Mean ± SD, I = Daily, II = Once a week (Monday), III = Alternatively (Monday, Tuesday and Thursday)*
- *Values with different superscripts in the column for each mode of application indicate significant difference in percent repellency among the four days of application at $P \leq 0.05$.*
- *Values with different superscripts in a row for each method of application indicate significant difference in percent repellency between the two sexes at $P \leq 0.05$.*

Table 12. Percent repellency with 10% eucalyptus oil when applied using three different methods against *Rattus rattus*

Mode of application	Days of application	Percent repellency					
		Paint		Block		Spray	
		Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)
I	Day 1	63.84±27.40 ^{a}	97.60±5.35 ^{b}	50.21±28.791 ^{a}	84.45±16.19 ^{b}	64.79±42.73 ^{a}	83.13±37.18 ^{a}
	Day 2	61.30±32.44 ^{ab}	82.54±36.95 ^{bd}	34.54±33.31 ^{a}	49.98±37.71 ^{b}	91.46±9.90 ^{a}	76.99±31.96 ^{a}
	Day 3	62.03±30.99 ^{ac}	23.51±37.35 ^{c}	45.66±27.92 ^{a}	76.11±17.16 ^{ab}	63.96±34.45 ^{a}	59.36±33.00 ^{a}
	Day 4	38.90±26.38 ^{ac}	50.00±50.00 ^{cd}	33.64±35.67 ^{a}	84.38±19.81 ^{b}	71.08±34.40 ^{a}	72.26±40.40 ^{a}
	Average	**56.51±10.21** ^{A}	**63.41±28.75** ^{A}	**41.01±7.11** ^{A}	**73.73±14.12** ^{B}	**72.82±11.10** ^{A}	**72.93±8.73** ^{A}
II	Day 1	69.46±16.68 ^{a}	45.00±35.57 ^{ab}	37.37±22.86 ^{ab}	36.09±22.55 ^{bc}	76.24±36.25 ^{a}	80.07±28.35 ^{a}
	Day 2	45.47±36.02 ^{a}	42.97±38.57 ^{ab}	20.81±21.58 ^{a}	16.59±20.90 ^{ab}	79.05±35.89 ^{a}	50.82±36.93 ^{ab}
	Day 3	29.35±24.78 ^{a}	20.79±35.96 ^{ab}	14.91±25.88 ^{a}	9.74±14.90 ^{a}	32.52±42.07 ^{ab}	13.15±29.41 ^{b}
	Day 4	50.86±31.77 ^{a}	0.00±0.00 ^{b}	19.13±22.91 ^{ac}	39.70±14.26 ^{c}	36.24±38.92 ^{ab}	30.19±43.04 ^{b}
	Average	**48.78±14.32** ^{AB}	**27.19±18.34** ^{B}	**23.05±8.53** ^{A}	**25.53±12.66** ^{A}	**56.01±21.69** ^{B}	**43.55±24.94** ^{B}
III	Day 1	47.34±35.23 ^{a}	62.60±38.72 ^{ac}	41.28±39.35 ^{a}	63.34±13.76 ^{a}	59.90±38.95 ^{a}	92.34±6.16 ^{a}
	Day 2	30.78±26.41 ^{a}	78.11±35.66 ^{c}	36.80±30.93 ^{a}	58.57±35.04 ^{a}	46.12±33.78 ^{a}	70.08±37.76 ^{a}
	Day 3	59.37±31.25 ^{a}	7.42±12.16 ^{b}	22.30±31.38 ^{ab}	12.56±6.49 ^{b}	19.81±20.87 ^{ab}	8.10±11.46 ^{b}
	Day 4	37.41±33.55 ^{a}	50.11±38.45 ^{ac}	42.46±30.13 ^{a}	39.31±32.41 ^{a}	12.88±20.61 ^{a}	45.27±42.73 ^{a}
	Average	**43.72±10.78** ^{A}	**49.56±27.27** ^{A}	**35.71±8.02** ^{A}	**43.44±19.97** ^{AB}	**34.67±19.12** ^{C}	**53.94±31.27** ^{ABC}

- *Values are Mean ± SD, I = Daily, II = Once a week (Monday), III = Alternatively (Monday, Tuesday and Thursday)*
- *Values with different superscripts in the column for each mode of application indicate significant difference in percent repellency among the four days of application at $P \leq 0.05$.*
- *Values with different superscripts in a row for each method of application indicate significant difference in percent repellency between the two sexes at $P \leq 0.05$.*

Table 13. Percent repellency with 20% eucalyptus oil when applied using three different methods against *Rattus rattus*

Mode of application	Days of application	Percent repellency					
		Paint		Block		Spray	
		Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)
I	Day 1	50.30±29.78 ^{a}	87.37±19.08 ^{b}	33.03±35.58 ^{a}	68.42±19.96 ^{b}	62.54±44.80 ^{a}	64.39±36.91 ^{a}
	Day 2	44.06±31.85 ^{a}	49.44±20.43 ^{ab}	31.96±34.61 ^{a}	23.56±15.24 ^{ab}	29.10±33.27 ^{a}	43.30±29.94 ^{a}
	Day 3	44.43±20.20 ^{a}	87.73±19.34 ^{b}	42.87±32.04 ^{a}	44.60±26.22 ^{ab}	54.87±29.31 ^{a}	63.68±23.41 ^{a}
	Day 4	42.45±22.74 ^{a}	58.22±39.53 ^{ab}	41.06±24.53 ^{a}	65.12±26.22 ^{ab}	58.12±32.28 ^{a}	74.68±35.68 ^{a}
	Average	**45.31±2.97** ^{A}	**70.69±17.14** ^{B}	**37.23±4.79** ^{A}	**50.42±17.99** ^{A}	**51.15±13.02** ^{A}	**61.51±11.38** ^{A}
II	Day 1	35.46±37.22 ^{a}	80.25±26.66 ^{b}	41.20±28.81 ^{a}	48.33±24.72 ^{a}	85.37±25.68 ^{a}	64.12±42.80 ^{a}
	Day 2	49.23±15.23 ^{ab}	66.83±26.61 ^{b}	43.92±36.03 ^{a}	68.96±21.39 ^{a}	60.10±44.72 ^{ab}	60.53±44.73 ^{a}
	Day 3	49.74±40.59 ^{a}	28.00±30.12 ^{a}	19.20±21.26 ^{a}	39.41±26.58 ^{a}	43.68±43.98 ^{bc}	57.84±41.90 ^{ab}
	Day 4	18.29±19.07 ^{a}	18.51±20.05 ^{a}	39.69±20.32 ^{a}	29.57±34.58 ^{a}	20.50±29.51 ^{c}	49.67±39.28 ^{a}
	Average	**38.18±12.83** ^{A}	**48.39±25.80** ^{AB}	**36.00±9.81** ^{A}	**46.56±14.53** ^{A}	**52.41±23.66** ^{A}	**58.04±5.32** ^{A}
III	Day 1	49.51±28.60 ^{a}	62.33±45.02 ^{a}	56.62±23.13 ^{a}	61.54±30.00 ^{a}	77.54±34.41 ^{a}	62.32±34.06 ^{a}
	Day 2	66.56±30.89 ^{a}	81.58±19.79 ^{a}	52.12±23.13 ^{a}	56.62±13.30 ^{a}	62.98±45.20 ^{a}	85.80±22.19 ^{a}
	Day 3	35.52±28.20 ^{a}	66.55±36.68 ^{a}	20.22±22.67 ^{b}	15.32±22.21 ^{b}	51.98±45.27 ^{a}	50.76±43.24 ^{a}
	Day 4	72.81±25.84 ^{a}	49.40±33.20 ^{a}	65.88±12.61 ^{a}	19.24±15.99 ^{b}	50.24±49.75 ^{a}	43.39±44.80 ^{a}
	Average	**56.10±14.62** ^{A}	**64.96±11.48** ^{AB}	**48.68±17.16** ^{A}	**38.18±21.01** ^{A}	**60.68±10.88** ^{A}	**60.56±16.05** ^{A}

- *Values are Mean ± SD, I = Daily, II = Once a week (Monday), III = Alternatively (Monday, Tuesday and Thursday)*
- *Values with different superscripts in the column for each mode of application indicate significant difference in percent repellency among the four days of application at $P \leq 0.05$.*
- *Values with different superscripts in a row for each method of application indicate significant difference in percent repellency between the two sexes at $P \leq 0.05$.*

Table 14. Percent repellency with 5% citronella oil when applied using three different methods against *Rattus rattus*

Mode of application	Days of application	Percent repellency					
		Paint		Block		Spray	
		Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)
I	Day 1	15.70±19.22 [a]	37.88±31.71 [ab]	61.38±37.45 [a]	48.00±48.17 [a]	36.78±32.47 [a]	73.48±34.43 [a]
	Day 2	10.29±10.34 [a]	41.20±28.93 [b]	16.66±37.26 [a]	55.09±39.83 [a]	57.44±37.61 [a]	58.90±29.30 [a]
	Day 3	19.88±17.85 [a]	42.16±32.20 [ab]	26.52±33.76 [a]	45.93±39.64 [a]	61.95±26.17 [a]	66.88±31.78 [a]
	Day 4	23.59±23.14 [a]	12.94±9.22 [ab]	33.53±25.29 [a]	12.56±19.01 [a]	58.88±31.96 [a]	48.87±33.39 [a]
	Average	**17.36±4.94 [A]**	**33.54±12.00 [AB]**	**34.52±16.62 [A]**	**40.39±16.42 [A]**	**53.76±9.93 [A]**	**62.03±9.18 [A]**
II	Day 1	39.16±26.89 [a]	40.19±35.85 [a]	66.89±27.41 [a]	54.06±31.15 [ab]	36.70±34.74 [a]	76.73±32.02 [b]
	Day 2	32.11±32.86 [a]	16.26±23.41 [a]	36.96±28.49 [b]	55.13±37.88 [ab]	26.39±27.12 [a]	37.50±40.18 [ab]
	Day 3	23.77±27.90 [a]	26.17±37.15 [a]	12.77±18.07 [b]	57.26±25.65 [a]	28.43±41.09 [a]	55.00±42.32 [ab]
	Day 4	12.90±22.13 [a]	5.23±7.41 [a]	25.02±20.91 [b]	24.97±19.41 [ab]	44.85±32.02 [a]	61.83±26.62 [ab]
	Average	**26.98±9.78 [A]**	**21.96±12.86 [A]**	**35.41±20.08 [A]**	**47.85±13.26 [A]**	**34.09±7.31 [B]**	**57.76±14.09 [A]**
III	Day 1	17.41±27.93 [a]	32.09±33.58 [a]	43.07±38.86 [a]	65.36±35.68 [a]	24.69±19.62 [a]	42.22±30.62 [a]
	Day 2	33.50±40.13 [a]	44.61±32.15 [a]	33.51±40.12 [a]	44.61±32.15 [a]	29.27±29.36 [a]	51.58±39.86 [a]
	Day 3	25.56±35.15 [a]	57.84±41.46 [a]	49.53±41.32 [a]	53.11±43.82 [a]	42.38±43.38 [a]	29.45±29.52 [a]
	Day 4	55.31±33.53 [a]	47.94±36.76 [a]	18.62±21.05 [a]	42.17±44.98 [a]	26.93±39.66 [a]	33.33±47.14 [a]
	Average	**32.94±14.11 [AB]**	**45.62±9.20 [B]**	**36.18±11.63 [A]**	**51.31±9.07 [A]**	**30.81±6.86 [B]**	**39.14±8.54 [AB]**

- *Values are Mean ± SD, I = Daily, II = Once a week (Monday), III = Alternatively (Monday, Tuesday and Thursday)*
- *Values with different superscripts in the column for each mode of application indicate significant difference in percent repellency among the four days of application at $P \leq 0.05$.*
- *Values with different superscripts in a row for each method of application indicate significant difference in percent repellency between the two sexes at $P \leq 0.05$.*

Table 15. Percent repellency with 10% citronella oil when applied using three different methods against *Rattus rattus*

Mode of application	Days of application	Percent repellency					
		Paint		Block		Spray	
		Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)
I	Day 1	39.15±26.12 ^{a}	46.04±36.34 ^{ab}	67.27±39.54 ^{a}	66.16±20.83 ^{a}	31.98±31.19 ^{a}	67.58±34.43 ^{b}
	Day 2	71.81±34.21 ^{a}	58.02±27.87 ^{ab}	51.11±45.49 ^{a}	63.39±28.58 ^{a}	58.24±35.40 ^{a}	82.69±15.44 ^{ab}
	Day 3	52.24±19.51 ^{a}	59.48±33.19 ^{ab}	41.22±33.86 ^{a}	25.80±31.83 ^{a}	52.77±33.50 ^{a}	55.35±38.00 ^{ab}
	Day 4	82.41±15.71 ^{a}	47.99±35.39 ^{b}	81.68±23.03 ^{a}	52.69±25.40 ^{a}	42.26±37.56 ^{a}	44.80±34.83 ^{ab}
	Average	**61.40±16.79** ^{A}	**52.88±5.93** ^{A}	**60.32±15.44** ^{A}	**52.01±15.94** ^{A}	**46.31±10.07** ^{A}	**62.60±14.12** ^{A}
II	Day 1	68.41±33.19 ^{a}	30.40±22.51 ^{b}	60.19±28.48 ^{a}	59.98±25.40 ^{a}	50.96±36.57 ^{a}	46.12±38.53 ^{a}
	Day 2	29.69±27.60 ^{bc}	31.63±33.77 ^{ab}	61.12±28.48 ^{a}	41.30±32.47 ^{a}	55.55±35.12 ^{a}	33.33±29.85 ^{a}
	Day 3	11.39±16.34 ^{b}	5.86±11.79 ^{ab}	6.89±15.41 ^{b}	7.67±9.83 ^{b}	11.10±16.16 ^{a}	19.57±10.33 ^{a}
	Day 4	44.60±23.39 ^{ac}	33.14±26.26 ^{ab}	12.68±26.83 ^{b}	9.46±12.01 ^{b}	44.63±23.37 ^{a}	53.09±37.93 ^{a}
	Average	**38.52±20.88** ^{B}	**25.25±11.24** ^{B}	**35.22±25.51** ^{A}	**29.60±22.05** ^{A}	**40.56±17.44** ^{AB}	**38.02±12.79** ^{B}
III	Day 1	43.74±17.46 ^{a}	58.33±27.83 ^{ab}	90.22±10.50 ^{a}	79.08±12.25 ^{a}	40.29±40.68 ^{a}	46.12±46.31 ^{a}
	Day 2	27.75±21.69 ^{a}	61.75±34.63 ^{b}	43.39±45.39 ^{b}	37.07±37.57 ^{ab}	34.97±24.39 ^{a}	27.96±17.21 ^{a}
	Day 3	29.87±34.35 ^{a}	25.81±31.81 ^{ab}	14.57±15.92 ^{b}	27.59±30.20 ^{ab}	32.71±20.44 ^{a}	40.48±19.86 ^{a}
	Day 4	61.75±23.11 ^{a}	20.61±19.16 ^{b}	37.62±38.14 ^{b}	30.79±27.41 ^{ab}	40.29±25.66 ^{a}	48.26±26.42 ^{a}
	Average	**40.77±13.57** ^{AB}	**41.62±18.54** ^{A}	**46.45±27.47** ^{A}	**43.63±20.74** ^{A}	**37.06±3.32** ^{AB}	**40.70±7.88** ^{B}

- *Values are Mean ± SD, I = Daily, II = Once a week (Monday), III = Alternatively (Monday, Tuesday and Thursday)*
- *Values with different superscripts in the column for each mode of application indicate significant difference in percent repellency among the four days of application at $P \leq 0.05$.*
- *Values with different superscripts in a row for each method of application indicate significant difference in percent repellency between the two sexes at $P \leq 0.05$.*

Table 16. Percent repellency with 20% citronella oil when applied using three different methods against *Rattus rattus*

Mode of application	Days of application	Percent repellency					
		Paint		Block		Spray	
		Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)	Female rats (n = 6)	Male rats (n = 6)
I	Day 1	50.73±21.35 [a]	51.05±33.52 [a]	65.69±19.12 [a]	51.73±24.02 [ab]	51.55±24.68 [a]	47.93±48.11 [ab]
	Day 2	21.17±36.60 [a]	27.40±23.63 [a]	60.35±34.95 [a]	21.48±16.19 [b]	28.56±41.23 [a]	39.92±23.31 [ab]
	Day 3	16.02±12.78 [a]	11.02±7.52 [a]	34.75±37.11 [a]	47.86±32.60 [ab]	5.83±1.14 [a]	51.75±34.21 [b]
	Day 4	56.97±38.92 [a]	52.24±15.10 [a]	33.91±25.48 [a]	58.91±20.72 [ab]	29.03±24.03 [a]	40.45±30.66 [ab]
	Average	**36.22±17.85 [A]**	**35.42±17.22 [A]**	**48.67±14.47 [A]**	**44.99±14.14 [A]**	**28.74±16.17 [A]**	**40.45±5.01 [A]**
II	Day 1	54.71±15.02 [a]	36.57±21.03 [a]	67.68±30.46 [a]	53.44±39.62 [ab]	56.00±31.72 [a]	56.85±32.36 [a]
	Day 2	19.15±29.71 [ab]	15.03±17.67 [b]	23.26±28.41 [a]	35.13±41.45 [ab]	19.34±14.28 [a]	18.57±25.57 [a]
	Day 3	24.61±34.59 [ab]	4.67±6.97 [b]	23.24±24.92 [a]	11.77±17.20 [b]	12.95±26.30 [a]	22.79±24.67 [a]
	Day 4	50.32±32.36 [a]	15.33±15.52 [b]	38.01±34.37 [a]	22.23±35.89 [ab]	51.11±45.01 [a]	23.95±26.24 [a]
	Average	**37.19±15.51 [A]**	**17.90±11.60 [A]**	**38.04±18.13 [A]**	**30.64±15.54 [A]**	**51.11±18.92 [B]**	**30.5±15.34 [AB]**
III	Day 1	28.60±22.63 [ac]	39.82±10.72 [a]	75.74±29.44 [a]	67.11±23.07 [ab]	57.63±40.57 [a]	61.54±38.44 [a]
	Day 2	47.54±24.30 [c]	53.37±18.44 [ac]	48.72±32.54 [ab]	60.88±32.16 [b]	56.65±33.10 [a]	47.67±37.40 [a]
	Day 3	22.42±29.95 [ab]	5.60±8.56 [b]	19.65±32.00 [b]	36.14±23.88 [b]	59.28±42.85 [a]	27.78±23.12 [a]
	Day 4	1.77±2.54 [b]	17.39±33.07 [ab]	21.54±26.89 [b]	31.80±33.10 [b]	44.21±25.48 [a]	24.20±20.28 [a]
	Average	**25.08±16.33 [A]**	**29.04±18.66 [A]**	**41.41±22.91 [A]**	**48.98±15.25 [A]**	**44.21±5.98 [B]**	**40.29±15.17 [AB]**

- *Values are Mean ± SD, I = Daily, II = Once a week (Monday), III = Alternatively (Monday, Tuesday and Thursday)*
- *Values with different superscripts in the column for each mode of application indicate significant difference in percent repellency among the four days of application at $P \leq 0.05$.*
- *Values with different superscripts in a row for each method of application indicate significant difference in percent repellency between the two sexes at $P \leq 0.05$.*

In overall, a significant difference in the effect of treatment was observed between the two sexes with higher repellent effect in male rats as compared to female rats. A significant difference was observed between concentrations 5 and 10% and between 5 and 20% of citronella oil with higher repellent effect of oil at 10% concentration followed by 20 and 5%. A significant difference was also observed among the three methods of application with higher repellent effect of the oil when applied as spray followed by that when applied as encapsulated blocks and as paint. No significant difference was observed among the three modes of application. The treatment had significant effect on different days of treatment with significant difference between Days 1 and 3 as well as between days 2 and 3 of treatment. Food consumption was significantly low from treatment side of each chamber of a laboratory pen as compared to that observed from untreated side.

4. EVALUATION OF CHEMICAL COMPOUNDS FOR TOXIC AND ANTI-FERTILITY PROPERTIES FOR DATA GENERATION ON INDIAN RODENTS.

4.1.Chemical compounds with toxic properties

a. Evaluation of toxic properties of cholecalciferol against *B. bengalensis*: Different groups of male and female *B. bengalensis* were administered single oral doses dissolved in groundnut oil @ 20, 30, 40, 50, 80, 100 mg kg^{-1} bwt cholecalciferol through gavage tube. The least tolerated dose of cholecalciferol causing 100% mortality of *B. bengalensis* within 3-7 days in male and within 3-11 days in female rats was found to be 50 mg/kg bw (Table 17). The LD_{50} value of cholecalciferol in male and female rats was determined to be 30.93 and 34.94 mg/kg bw, respectively. Post-treatment bait consumption by both male and female rats was significantly low from pre-treatment bait consumption at all the doses tested. The level of calcium and phosphorus in serum of male and female rats after 48 h of treatment was found increased significantly at all the doses tested with highest increase at 50 mg/kg bw (Tables 18-19). Histopathological study of different tissues (heart, liver, lungs, kidneys, stomach, spleen, ovaries and testes) of treated and untreated rats revealed lymphomononuclear cell infiltration in response to toxicity of cholecalciferol along with cellular degeneration and mineralization. The study suggests the use of cholecalciferol as a rodenticide for managing population of *B. bengalensis* in crop fields and premises.

b. Acceptance and efficacy of bait containing cholecalciferol in poultry farm: Treatment of different poultry sheds at village Ghutani Kalan, Distt Ludhiana with 0.005% bromadiolone bait, 0.075% cholecalciferol bait and bait containing combination of 0.00125% bromadiolone and 0.01% cholecalciferol for 3 days revealed no significant difference in the acceptance of all the three types of baits. Percent control success (65-71%) was almost similar in all the three treated blocks. The cost of poison

in 0.005% bromadiolone, 0.075% cholecalciferol and combination of two used was worked out to be Rs 28, Rs 1350 and Rs 183, respectively. Since the control success with all the three treatments was at par and cholecalciferol helps in minimizing the resistance factor against bromadiolone and bromadiolone, the combination of the two is suggested for controlling *R. rattus* populations in poultry farms.

Table 17. Toxicity of single oral doses of cholecalciferol in *B. bengalensis*

Dose (mg/kg bw)	Male rats			Female rats		
	Body weight (g) (N=5 each)	Mortality (%)	Days to death (Range)	Body weight (g) (N=5 each)	Mortality (%)	Days to death (Range)
20	230.00 ± 29.58	20	4	179.20 ± 13.96	20	7
30	212.40±20.46	40	3-8	215.20 ± 23.86	20	9
40	234.60 ± 24.11	60	3-11	172.20 ± 21.45	40	6-10
50	299.80 ± 26.69	100	3-7	214.00 ± 24.53	100	3 - 11
80	232.00 ± 24.42	100	2-3	211.80 ± 18.27	100	3 - 9
100	231.20 ± 25.79	100	1-6	217.80 ± 37.29	100	2 - 7
Vehicle	212.60 ± 25.86	Nil	Nil	231.00 ± 37.74	Nil	Nil

Values are Mean ± SD

Table 18. Effect of cholecalciferol on levels of calcium in serum of B. bengalensis

Dose (mg/kgbw) (N=5 each)	Male rats		Female rats	
	Level of calcium in serum (mg/dL)		Level of calcium in serum (mg/dL)	
	At 0 h	At 48 h	At 0 h	At 48 h
20	8.17 ± 0.50	8.43 ± 0.91	6.32 ± 0.57	7.49 ± 0.76
30	7.98 ± 1.08	9.29 ± 0.96	6.25 ± 0.63	8.06 ± 0.59*

40	7.61 ± 0.51	10.42 ± 0.89*	6.48 ± 0.50	9.94 ± 0.85*
50	7.62 ± 0.45	12.12 ± 0.92*	6.45 ± 0.52	10.49 ± 0.64*
80	8.09 ± 1.10	8.57 ± 1.10	6.14 ± 0.52	7.17 ± 0.61
100	8.20 ± 0.80	9.95 ± 0.92	6.04 ± 0.50	7.33 ± 0.64
Vehicle	7.86 ± 1.04	7.86 ± 1.10	6.28 ± 0.51	6.32 ± 0.50

Values are Mean ± SD, * significant difference between 0 and 48 hr

Table 19. Effect of cholecalciferol on levels of phosphorous in serum of *B. bengalensis*

Dose (mg/kgbw) (N=5 each)	**Male rats**		**Female rats**	
	Level of phosphorus in serum (mg/dL)		**Level of phosphorus in serum (mg/dL)**	
	At 0 h	**At 48 h**	**At 0 h**	**At 48 h**
20	4.67 ± 0.45	6.01± 0.59	4.05 ± 0.61	5.86 ± 0.54*
30	4.47 ± 0.44	8.04 ± 0.44*	3.13 ± 0.48	6.36 ± 0.51*
40	4.50 ± 0.85	8.41 ± 1.24*	3.32 ± 0.53	7.61 ± 0.66*
50	4.69 ± 0.63	10.42 ± 1.42*	3.94 ± 0.85	9.30 ± 0.97*
80	4.57 ± 0.50	8.98 ± 0.82*	3.20 ± 0.61	6.16 ± 0.73*
100	4.71 ± 0.65	9.13 ± 0.62*	3.42 ± 0.73	7.45 ± 0.59*
Vehicle	4.64 ± 0.56	4.64 ± 0.53	3.65 ± 0.77	3.67 ± 0.79

Values are Mean ± SD, * significant difference between 0 and 48 hr

4.2.Chemical compounds with antifertility properties

a. Antifertility properties of nifedipine, a chemosterilant against male *R. rattus:* Feeding of bait containing 0.1 and 0.2% nifedipine, a chemosterilant for 12 days in no-choice to male *R. rattus* resulted in ingestion of 0.09 and 0.16 g/kg of the active ingredient. No significant difference was found in the consumption of treated and untreated bait indicating good acceptability of bait containing nifedipine. No significant antifertility effect of treatment was observed after 50 days of termination of treatment, indicating reversible antifertility effects of nifedipine.

b. Antifertility properties of immidazole, a chemosterilant against male *R. rattus:* Feeding of WSO bait containing immidazole in choice with plain bait and leading to

ingestion of 40 and 160mg/kg bw of immidazole revealed no effect of treatment on weights of testis and epididymis. A reduction in sperm motility and concentration in the cauda epididymal fluid of the treated group of rats was observed but no effect of treatment was recorded on sperm viability, sperm morphology and on decondensation of sperm heads indicating that sperms were capable of fertilizing the oocytes (Table 20). There was also no effect of treatment on length of estrous cycle and none of the untreated and treated female R. rattus paired with treated and untreated male rats, respectively delivered pups. From the above results, it is clear that 40 mg/kg bw of imidazole was not enough to induce antifertility effect in rats of both sexes. In rats fed on 160 mg/kg bw of imidazole, again there was no effect on weights of reproductive organs but there was reduction in sperm motility and concentration with increase in number of sperms with displaced head in the cauda epididymal fluid of the treated group of rats. There was no effect of treatment on sperm viability. Moreover no estrous cyclicity was recorded in females treated with 160mg imidazole and none of the untreated and treated female R. rattus paired with treated and untreated male rats, respectively delivered pups (Table 20).

Table 20. Effect of imidazole (40mg) on weights of reproductive organs and sperm parameters of male *R. rattus* after 30 days of termination of treatment

Parameters	**Treated (40mg)**	**Treated (160mg)**	**Untreated**
Body Weight (g)	156.67±5.45	155.67±6.61	140.30±8.71
Weight of testis (g/100g bw)	0.76±0.03	0.75±0.01	0.70±0.14
Weight of epididymis (g/100gbw)	0.27±0.04	0.31±0.02	0.22±0.01
Sperm motility (%)	26.67±9.82	43.33±2.72	90.00±0.01
Sperm viability (%)	68.29±7.60	69.20±3.59	59.00±14.89
Sperm concentration (millions/ml)	32.67±8.07	23.00±11.97	171.40±46.38
Sperm abnormalities (Abnormal head position)	13.85±0.19	46.52±9.38	10.00±1.70
% Decondensed head (NCD test)	60.52±4.40	-	68.00±7.30
Days of estrous cycle (range)	3-5	No cyclicity	3-5

-Values are Mean ± SE

5. DEVELOPMENT OF RODENT MANAGEMENT TECHNOLOGIES UNDER STORAGE CONDITIONS

5.1. Effect of different treatments on rodent population in stores

Survey of indoor stores at villages Khanna, Mullanpur and Jagraon in district Ludhiana revealed poor rodent proofing, as shutters of these stores were either broken or there was sufficient space between floor/walls and shutter allowing rat entry inside the stores. In addition iron meshes of windows were also broken. Height of plinths of indoor MARKFED stores was only 1.5 to 2.0 feet, which was not enough to restrict rodent entry into the stores. Moreover these plinths were damaged and surrounded by grass, weeds and heaps of soil allowing easy assess of rodents to stores. Also there was poor environmental sanitation in MARKFED stores giving hiding places to rodents. However, rodent damage in FCI stores was comparatively less. It might be because these stores were at the height of about 2.5 feet but still temporary stairs were attached to plinths again allowing rodents to go up. One of the surveyed FCI rice store was at the height of only about 1 foot, located at place with minimum human disturbance and was surrounded by weeds and plants. In this store rodent damage was maximum, spilled rice grains were mixed with rat pellets, bags were cut (37.33%) and dead rats were also seen below crates. Rodent cuts were observed on bags upto 5^{th} layer with maximum damage on bags of 1st and 2^{nd} layer of stacks.

Survey of outdoor FCI (village Khanna, district Ludhiana) and MARKFED (Mullanpur, district Ludhiana) stores revealed poor sanitation conditions and stacks were either kept on wooden crates on kacha floor or on plinths of about 1.5 feet height which were not enough to restrict rat entry into stacks. Moreover, plinths were either damaged or surrounded by weeds and heaps of soil making it easy for rats to assess stacks. Only control measure being used in these stores was fumigation of stacks twice or thrice in a year which was not enough to control rats. Sanitation conditions in PUNGRAIN store surveyed at Jagraon, district Ludhiana was comparatively better with no weeds surrounding plinths and plinths were well structured and cemented. Bags were kept on plastic crates about 6 inches in height allowing easy inspection of stacks for rodents and reducing harborage sites for rats.

Survey of rodent damage in a newly constructed grain store at village Mullanpur, district Ludhiana revealed negligible damage by rodents. There was minor spillage in stores, bags were kept on stands and there was a space of around 1 meter around the stacks and there were no weeds and heaps of soil or stairs around the store platform. Moreover, these stores were constructed on a platform at a height of about 2.5 feet with an extension of about 1 foot only in the front portion of platform perimeter. It was felt that this extension of 1 foot should be all around the platform so as to prevent the rats from climbing up the platform.

Three outdoor wheat grain stores at villages Ajitwal in district Moga and village Mullanpur in district Ludhiana and treated with celphos in mid December, 2014 and last week of January, 2015 were surveyed at monthly intervals to record the effect of treatment on rodent activity. Results revealed increase in rodent activity in March, 2015 indicating the effectiveness of celphos for 1-2 months (Table 21). Treatment of small stacks of five bags each with cinnamic aldehyde formulation containing sodium bicarbonate as emulsifier resulted in no rodent damage up to 15 days of treatment

Three outdoor paddy stores where stacking was done in November, 2014 were selected to assess the effect of storage period on rodent population. In these stores, no treatment was done to reduce rodent population. Rodent population as estimated by bait census method in January and February, 2015 revealed increase in bait consumption with increase in storage period from 25.04 in January, 2015 to 38.08 in February, 2015 (Table 21). Three small stacks of five bags each were constructed in these stores and were treated with cinnamic aldehyde formulation containing sodium bicarbonate as emulsifier and recorded rodent damage after 15 days of treatment. No cuts or faecal pellets were seen on these bags after 15 days of treatment.

Three indoor rice stores where stacking was done in December, 2014 were selected to assess the effect of storage period and different treatments (rodent proofing+ environmental sanitation+celphos) on rodent population. These stores were maintaining environmental sanitation and were constructed at a height of 2.5 feet but collar guard was not extended all around the perimeter. Celphos treatment was done in these stores in January, 2015. Rodent population was estimated by bait census method in January and March, 2015. Results revealed only 13.6 and 18.56 percent bait consumption in January and February, 2015, respectively (Table 21). Very low bait consumption in these stores might be due to environmental sanitation and rodent proofing thus reducing access of rodents to stored bags. Complete rodent proofing in these stores might completely prevent access of rodents to these stores.

Table 21. Estmation of rodent population in grain stores by bait census method

Store	**Crop (number of stores)**	**Treatment (time of treatment**	**Plain bait consumption (%)**		
			Jan,15	**Feb, 15**	**Mar, 15**
Outdoor	Wheat (3) stacked in May	Celphos (mid December and last week of January	31.3±3.87	36.3±8.10	56.2±6.97

Outdoor	Rice (3) Stacked in November	Big stacks were not treated	25.04±7.94	38.08±4.64	-
Indoor	Rice (3) Stacked in December	Rodent proof+ environmental sanitation +celphos	13.6±4.35	-	18.56±4.89

Four wheat grain stores at villages Mudhiani, Sidhwan Kalan and Sohian, district Ludhiana were surveyed in May, 2012 for rodent damage. Number of stacks in grain stores I, II and III were 24 and in grain store IV were 56. In one stack, number of wheat bags ranged from 3220 to 3260. Mostly wheat is stored in these stores for 6 to 18 months. In grain stores I and II, bags were kept on wooden stand lying on cemented/kucha floors, in grain store III, wheat bags were stored both on plinths (height 1.5 feet) as well on cemented floor directly while in store IV, wheat bags were kept on plinths only. Survey from store owners revealed that for pest control, they treat all the stacks with celphos (aluminium phosphide) tablets supplied by government agencies after every three months @ 320-450 tablets/stack by keeping tablets on wheat bags as such. After treating stacks with celphos they cover stacks with black polythene sheets and seal it with heaps of soil for 7-10 days to kill all the insect pests including rodents. But store owners reported that even after treatment with celphos for about four times in a year, lower layer of bags in a stack is mostly damaged and infested by rodents. Rodent damage was recorded in these stores by recording plain bait consumption. These stores were again surveyed in the mid of July, 2012. Stores I-III were treated with celphos in the Ist week of July, 2012 while store IV was last treated by owner in April, 2012 so there was no effect of celphos in this store. Rodent damage was again recorded in these stores by recording plain bait consumption. Consumption of plain bait in these stores ranged from 38.5 to 66.5%. Stores II-IV were treated with 0.005% bromadiolone by keeping bromadiolone bait @50gm/stack but store I was not treated with bromadiolone. Post census plain bait consumption was recorded in August, 2012 to determine the effect of treatment. Results revealed more rodent control success in stores treated with celphos and bromadiolone than those treated with celphos alone.

5.2. Potential of different formulations of cimnnamic aldehyde under simulated storage conditions

Three formulations of effective doses of each compound (5% cinnamic aldehyde and 0.4% cinnamamide) were prepared and exposed to *R. rattus* of both sexes. Formulations I and II of cinnamic aldehyde were used as spray and formulation III was in the form of a chalk, which was used to draw lines around and on the bags. Results revealed a

non-significant difference in consumption of wheat grains, number of cuts, size of cuts, quantity of spilled grains and urine contamination of spilled wheat grains and grains filled in bags between the two sexes. In overall, there was less consumption and spillage from bags treated with formulation II of cinnamic aldehyde as compared to bags treated with formulation I and III both after 7 and 15 days of spraying (Table 22). There was less consumption and spillage from bags treated with formulation III of cinnamamide as compared to bags treated with formulation I and II both after 7 and 15 days of spraying (Table 23).

There was no degradation of cinnamic aldehyde in formulation II and cinnamamide in formulation III with time and sodium bicarbonate mixed in this formulation not only acted as emulsifier but might also reduced degradation, increased stickiness on bags and synergized the antifeedant effect of cinnamic aldehyde and cinnamamide.

Table 22. Antifeedant index and consumption of wheat from bags treated with different formulations of 5% cinnamic aldehyde

Formulations	After 7 days			After 15 days		
	Consumption of wheat (g/100g bw/day)		Anti feedant Index (%)	Consumption of wheat (g/100g bw/day)		Anti feedant Index (%)
	Untreated	Treated		Untreated	Treated	
I	3.62± 1.12 [a]	7.17± 1.99[a]	-	3.06± 1.01[1]	7.38± 1.19[1]	-
II	6.62± 1.54 [a]	1.12± 0.54 [b]	68.05± 14.36	8.52± 0.69[1]	1.12± 0.32[2]	77.25± 6.07
III	3.26± 1.19[a]	3.64± 0.73[ab]	-	5.64± 0.59[1]	3.78± 0.77[12]	27.69± 11.12

Values are Mean±SE, Number of rats = 6 (3 males and 3 females)

[a, b] Significant difference in food consumption in rows as well as along the columns after 7 days of treatment

[1, 2] Significant difference in food consumption in rows as well as along the columns after 15 days of treatment

Table 23. Antifeedant index and consumption of wheat from bags treated with different formulations of 5% cinnamamide after 7 and 15 days of treatment

Formulations	After 7 days			After 15 days		
	Consumption (g/100g bw/day) of wheat		Anti feedant Index (%)	Consumption (g/100g bw/day) of wheat		Anti feedant Index (%)
	Untreated	Treated		Untreated	Treated	
I	3.14± 1.02[a]	3.84± 0.55[ab]	-	3.19± 0.84[1]	2.30± 0.45[1]	12.09± 7.46
II	2.97± 0.3[a]	6.15± 1.78[a]	-	2.28± 0.49[1]	5.52± 1.05[2]	-
III	4.47± 0.66[ab]	1.44± 0.60[b]	55.09± 17.38	4.24± 0.46[1]	0.87± 0.35[3]	68.03± 12.98

Values are Mean±SE, Number of rats = 6 (3 males and 3 females)

[a, b] Significant difference in food consumption in rows as well as along the columns after 7 days of treatment

[1, 2,3] Significant difference in food consumption in rows as well as along the columns after 15 days of treatment

5.3. Potential of eucalyptus and citronella oils as repellents in stores

Results of experiment conducted in store houses using 5% eucalyptus and 5% citronella oils as encapsulated wax blocks and as spray revealed a significantly low consumption of food in the stores treated with eucalyptus oil as compared to untreated stores and stores treated with citronella oil. Significantly reduced consumption of food was observed during post-treatment bait census in stores treated with eucalyptus and citronella oils compared to untreated group of stores indicating the effect of treatment even after its termination. Percent repellency with encapsulated wax blocks of 5% eucalyptus oil was found to be significantly more than that observed in stores treated with encapsulated wax blocks of citronella oil. No significant difference in percent repellency was, however, observed in stores treated with eucalyptus and citronella oils as spray thus indicating the superiority of encapsulated wax blocks over spray and of eucalyptus oil over citronella oil. The percent control success with respect to same store was found to be significantly high in stores treated with eucalyptus oil than those treated with citronella oil (Table 24).

Table 24. Percent repellency and percent control success with treatment of eucalyptus (5%) and citronella oil (5%) in stores infested mainly with *Rattus rattus*

Store group (n=3 each)	Treatment	Percent repellency		Percent control success with respect to	
		With blocks	With spray	Same store	Untreated store
I	EO	72.24±4.60 [a]	67.33±4.66 [a]	70.37±5.33[a]	82.91±3.07[a]
II	CO	47.89±11.45[b]	62.45±12.52[a]	56.66±11.36[b]	75.01±6.54[b]
III	Untreated	-	-	-	-

-Values are Mean ± SD, EO = Eucalyptus oil, CO = Citronella oil

-Values with different superscripts in a column differ significantly at $P \leq 0.05$

6. BIO-ECOLOGY OF *TATERA INDICA*

Burrowing rodents live in different habitats by forming simple and shallow to deep and complex network of tunnels with variable numbers of surface opening. The length, depth, surface opening, chambers of burrows may be affected by soil quality, food availability and colony size. Studies on the burrowing habit of rodent pests are required to understand their social organization, ecology and behaviour. About 40 burrows of *T. indica* were excavated in loamy sand soil of village Ladhowal, Distt Ludhiana during May-June and their morphometric measurements were recorded. The depth of excavated burrows ranged from 22.5 to 112.5cm. Burrows were having hoarded material in the form of wheat tillers weighing 250g to 1400g. Number of open ends and blind ends of dug burrows ranged from 1-4 and 0-6, respectively. Burrows were both simple and complicated with one to four chambers in which food and nests were found. During digging of one burrow, 6 pups (4 females and 2 males) of about one month age were found. While digging of one burrow in October-November also, one female with 7 pups was found thus indicating these months to be the breeding season for *T. indica.*

Morphometric measurements (Table 25) of 46 mature male and female *T. indica* collected from Ladhowal Seed Farm, PAU, Ludhiana and from Bathinda revealed body length and body weight of male gerbils ranging from 23.0–37.0 cm and 55.0–190.0gm, respectively and of female gerbils ranging from 16.0-35.0 cm and 36.0–173.0gm, respectively. Ears, tail and feet of rats were hairy, fur was golden brown on dorsal side and white on ventral side. Four pairs of mammae were recorded on the ventral side of each female rat. Both fore and hind limbs possessed five digits.

Table 25. Morphometric measurements of male and female *T. indica*

Sr.No.	Body parameters	Male (n=20)	Female (n=26)
1.	Body colour and fur on dorsal surface	Golden brown	Golden brown
2.	Body colour and fur on ventral surface	white	white
3.	Number of mammae	-	4+4 paired
4.	Body weight (g)	55.0 – 190.0	36.0 – 173.0
5.	Total length of body (cm)	23.0 – 37.0	16.0-35.0
6.	Head length (cm)	3.0 - 5.5	3.0-5.0
7.	Length of body (cm)	8.0-17.0	6.0-15.0
8.	Length of tail (cm)	12.0 – 18.0	8.0-18.0
9.	Tail hairs	Hairy with tuft of hair at tip	Hairy with tuft of hair at tip
10.	Tail annulations	No	No
11.	Ear colour	Greyish black, brown	Greyish black, brown
12.	Ear hairy or naked	hairy	hairy
13.	Ear length (cm)	1.0-2.2	1.0-2.0
14.	Size of eye (cm)	0.5-1.5	0.5-1.5
15.	No. of digits in fore limb	5	5
16.	No. of digits in hind limb	5	5
17.	Feet hairy or not	hairy	hairy
18.	No. of incisors	2+2	2+2
19.	Length of forelimb (cm)	2.5-6.5	2.5-6.5
20.	Length of hind limb (cm)	4.5-7.5	2.5-7.5
21.	Sole of feet	hairless	hairless

7. DEVELOPMENT/REFINEMENT OF RODENT PEST MANAGEMENT MODULES IN PREDOMINANT CROPS/CROPPING SYSTEMS.

7.1. Comparison for paper and tyre bait stations for rodenticide bait application in rice crop

The experiment conducted in rice fields at Ladhowal Seed Farm of PAU revealed no significant difference between percent control success by 2% zinc phosphide when applied using tyre bait stations (87.93%) and paper bait stations (65.59%). The cut tillers (0.70 %) and yield loss (98.27 kg/ha) (Table 25) were found to be lowest in block treated using tyre bait stations thus highlighting the efficacy of tyre bait stations for rodent control in rice crop as they were able to protect the poison bait in rainy weather.

Table 25. Relative consumption of zinc phosphide bait, percent control success and rodent damage in blocks with different bait stations

Bait station	Treatment	Poison bait consumption (%)	Control success (%)	Percent cut tillers	Yield loss (kg/ha)
Paper	Treated	81.58±8.04	65.59±15.72	0.81±0.42 [a]	105.87±63.84 [a]
Paper	Control	-	-	2.06±0.35 [b]	252.47±52.89 [b]
Tyre	Treated	59.50±7.53	87.93±5.47	0.70±0.06 [a]	98.27±11.08 [a]
Tyre	Control	-		2.51±0.14 [b]	342.53±40.77 [b]

Values are mean± SE

7.2. Determination of critical timings of rodent control in pea crop

The critical timings of rodent control in pea crop were determined by conducting an experiment at Naraingarh Seed Farm of PAU in district Fatehgarh Sahib. The rodent damage to pods was found to be minimum in blocks I (0.75%) and II (1.23%) which received four and three treatments of 2% zinc phosphide, respectively through burrow baiting i.e. after 30, 60, 90 and 120 days of sowing and after 30, 60 and 90 days of sowing of pea crop (Table 26). The data thus indicates the need for a minimum of three treatments at 30, 60 and 90 days after sowing to save the pea crop from rodent damage.

Table 26. The percent control success and percent damage to pods in different blocks

Block	Treatments	Control success (%) (wrt control)	Control success (%) (wrt same field)	Damage to pods (%)
I	Four (30, 60, 90, 120 DAS)	94.52 ±2.95 [b]	75.83± 13.26 [b]	0.75±0.75 [c]
II	Three (30, 60, 90 DAS)	83.44 ±12.53 [b]	88.18± 4.10 [b]	1.23±0.83 [c]
III	Two (30, 60 DAS)	90.57±1.68 [b]	57.58±7.58 [a]	5.35±0.75 [b]
IV	One (30 DAS)	12.96±12.96 [a]	0	6.76±1.77 [b]
V	Control	--	--	22.55±1.87 [a]

DAS: Days after sowing, Values are Mean ± SE ; Values with different superscripts in a column differ significantly at $P \leq 0.05$

7.3.Determination of methods of rodent control in direct seeded and transplanted basmati crops

To evaluate the frequency of baiting schedule in direct seeded and transplanted basmati rice crop, the experiments were conducted at villages Kangraur and Kataria of district Hoshiarpur. In this experiment, there were selected four blocks, I, II, III and IV each of direct seeded basmati rice (DSBR) and transplanted basmati rice (TBR) crops. In block I of each type of crop, single burrow baiting with zinc phosphide (2%), in block II single paper baiting with bromadiolone (0.005%), whereas in block III, both burrow and paper baiting were practiced and block IV was kept as control. Burrow baiting was done during vegetative stage of basmati crop and paper baiting during reproductive stage.

The data revealed 57.30, 44.47 and 65.64 % control success in blocks I, II and III belonging to DSBR, respectively. Similarly, in blocks I, II and III belonging to TBR fields, the per cent control success was recorded to be 58.44, 49.76 and 61.68 %, respectively (Table 27). In both the types of crops the control success was high in block III treated twice i.e., burrow baiting during vegetative and paper baiting during reproductive stage of crop. This was also supported by lower per cent cut tillers and per cent damage in both DSBR and TBR fields. Present studies thus suggest the conduction of two rodenticide treatments i.e. burrow baiting at vegetative and crop baiting at reproductive stage of the crop for effective control of rodents in direct seeded basmati and transplanted basmati rice crops.

Table 27. Per cent cut tillers and per cent control success in direct seeded and transplanted basmati rice crops

Blocks	Cut tillers (%)		Control Success (%)	
	DSBR	TBR	DSBR	TBR
I	0.64±0.03	0.67±0.10	57.30±3.17	58.44±2.52
II	0.76±0.04	0.60±0.13	44.47±2.37	49.76±5.87
III	0.43±0.03	0.37±0.06	65.64±4.72	61.68±6.51
IV	1.61±0.09	1.09±0.10	--	--

7.4. Rodent infestation, damage and control in crops grown under poly-houses

Regular survey of polyhouses of departments like Agronomy, Vegetable Science, Agrometeorology, Entomology, Plant Pathology and Soil & Water Engineering at PAU campus at monthly intervals revealed presence of burrows of *B. bengalensis* and *Mu*s *s*pp. inside as well as outside the poly houses. The rodents might have gained entry from the holes present in the net as well as by digging burrows from below the ground. No rodent damage was recorded in basil and baby corn grown in polyhouses at an area around Ladhowal Seed Farm owned by private company (Airtel Pvt. Ltd). These polyhouses were well managed and rodent proof with installation of about 2 feet high wall all around with a foundation of about 2-3 feet. There were no weeds in these crops. Surveys were also conducted in polyhouses at villages Muskabad (district Ludhiana) and Raunke Kalan (district Moga). The polyhouses were surveyed at different crop stages during the whole crop season to record any infestation by rodents. At village Muskabad, the main crop grown was cucumber by direct method of sowing. Before sowing i.e. one month prior, the farmer treated the soil with Formaldehyde @ 10%. After giving a single ploughing the soil was drenched with the formaldehyde solution and then plastic sheets were placed on the soil. After 1 week the plastic sheets were removed and soil was ploughed with tillage implements and crop was raised. The application of formaldehyde may have killed all the harmful microorganisms or pathogens/insects. Also, proper hoeings were done at regular intervals to remove any weed in all the polyhouses. At germination stage of the crop (in August), no activity of rat and no burrows were observed inside and outside the polyhouses. At vegetative stage (1 month after sowing in the end of October), also no rodent damage was observed in all the polyhouses. At fruiting stage (in the end of November), the polyhouses were found torn from outside at some places (near ground surface) due to farm operations or other reason. Rodent burrows were there but no damage to crop was observed. Farmers were suggested to keep check of holes in the polyhouses, so that no rodent can infest the polyhouse. Survey of six polyhouses containing capsicum crop at village Raunke Kalan revealed predominance of rodent burrows both within and outside the polyhouses with damage ranging from 0.56 to 3.8% on fallen fruits and no damage on fruits attached to plants.

7.5. Integrated control of rodent pests in sugarcane crop using triptolide

Farmer's fields of sugarcane crop infested mainly with *B. bengalensis* were selected at village Palahi, District Kapurthala, Punjab, India. Three separate blocks (I, II and III) of sugarcane fields were selected and pre-census bait consumption was recorded. After record of pre-census, fields of blocks II and III were given first treatment of 0.005% bromadiolone bait. After 15 days of first treatment with 0.005% bromadiolone, post census bait consumption was recorded from all the fields to determine the changes in level of rodent population. After first post-census, fields of block III were treated with 0.25% triptolide bait. After 15 and 30 days of second treatment with triptolide in block III, again post census, second and third was taken from all the fields.

First post census bait consumption after15 days of first treatment with 0.005% bromadiolone in fields of blocks II and III revealed 45.32 and 39.55% reduction in rodent population, respectively (Table 28). Second post census after fifteen days of 0.25% triptolide treatment in fields of block III revealed 74.14 and 90.02% reduction in rodent population in blocks II and III, respectively. Post census bait consumption after 30 days of triptolide treatment revealed 29.46 and 31.54% reduction in rodent population in blocks II and III, respectively indicating rebuildup in rodent population. From the reduction in rodent activity estimated after two treatments, per cent rodent population rebuildup was calculated to be 44.69% with respect to the same field in block II, treated only with bromadiolone and 58.48% in block III, treated with bromadiolone and triptolide both (Table 28). There was no significant difference in rodent population rebuildup as determined by two methods between the fields of blocks II and III. Rodent damage was significantly high in untreated fields.

Present studies could not clearly reveal the effect of triptolide treatment as the same was found combined with delayed effect of bromadiolone and migration of rodents to surrounding rice crop. Rodent population rebuildup observed after 30 days of triptolide treatment and 45 days of bromadiolone treatment during present studies may be due to the delivery of pups by the residual population of female rats after a gestation period of 21-23 days which were pregnant before treatment with triptolide and the effect of triptolide treatment might have come at a later stage.

Table 28. Effect of bromadiolone and triptolide treatments on reduction in rodent population in sugarcane crop fields

Treatment n=3 each)	Percent reduction in rodent population with respect to same fields			Population rebuildup with respect to same field	Cut canes (%)
	After 15 days of Br treatment	After 15 days of Trp treatment	After 30 days of Trp treatment		
Untreated	16.08± 1.69[a]	29.35± 6.24 [a]	8.38± 3.73 [a]	14.95±4.19[a]	2.27±0.11[a]
Br	45.32± 7.16 [b]	74.14± 6.78 [b]	29.46± 5.40 [b]	44.69±7.73 [b]	0.67±0.11[b]
Br+Trp	39.55± 3.57 [b]	90.02± 0.44 [b]	31.54± 8.04 [b]	58.48±7.62 [b]	0.53±0.29[b]

-Values are Mean ± SE, Br=0.005% bromadiolone, Trp=0.25% triptolide

7.6. Experiment on rodent control in wheat crop sown under rice and maize residues

To evaluate the frequency of baiting schedule in wheat crop grown with conventional tillage, zero tillage and Happy Seeder in rice residues and maize residues, experiments were conducted from at Borlaug Institute of South Asia (BISA), village Ladhowal, district Ludhiana. There were selected four blocks, I, II, III and IV of each type of crop In block I, double burrow treatment 1st with bromadiolone (0.005%) and 2nd with zinc phosphide (2%) (after 15 days) + single paper baiting with bromadiolone were practiced, in block II only single paper baiting with bromadiolone and in block III single burrow baiting with bromadiolone were practiced, whereas block IV was kept as control, where no treatment was done. Burrow baiting was done during vegetative stage of crop and paper baiting during reproductive stage of crop.

Results revealed higher per cent rodent control success (on plain bait consumption basis) in block I treated with double burrow baiting along with single paper baiting (69.72-82.81) than in blocks treated with single burrow baiting (43.31-51.11) and single paper baiting (54.42-61.46). Higher per cent control success was observed in blocks having wheat sown with conventional tillage method. Similarly, the per cent control success (on live burrow census basis) ranged from 74.54 to 92.12, 60.74 to 69.16 and 44.67 to 56.45 in blocks I, II and III, respectively, being higher in block I (Table 29). The fields were found mainly infested with *B. bengalensis* followed by *Mus*

spp. and *T. indica*. Cut tillers in treated blocks I, II and III ranged from 0.53 to 2.03% in fields with maize residue, 0.47 to 1.67% in fields with rice residue, 0.44 to 1.62% in fields with zero tillage and 0.39 to 1.58% in fields with conventional tillage. In control fields, cut tillers ranged from 2.55 to 4.65%.

Table 29. Per cent control success (on plain bait consumption basis) in wheat crop sown with different techniques at BISA, village Ladhowal, district Ludhiana

Blocks	Control success (%) on bait census basis			
	Happy Seeder		Zero tillage	Conventional tillage
	Maize residue	Rice residue		
I (Double burrow + single paper)	73.71±2.96	69.72±4.27	78.73±3.14	82.81±3.07
II (Single paper)	56.63±1.38	54.42±3.25	57.89±4.15	61.46±5.38
III (Single burrow)	46.89±2.49	47.25±2.21	43.31±2.65	51.11±6.20
IV (Control)	--	--	--	--

7.7. Rodent control in crops down under different residues at farm of Agronomy department, PAU campus

To determine methods of rodent control in wheat crop grown with conventional tillage, zero tillage and Happy Seeder in rice and maize residues, experiments were also conducted at Agronomy farm, PAU, Ludhiana by selecting four blocks, I, II, III and IV, respectively of four different types of crops. In all the blocks, two treatments were performed 1st burrow baiting with zinc phosphide (2%) at vegetative stage along with 2nd treatment of paper baiting with bromadiolone (0.005%) during reproductive stage, whereas two plots selected at Ladhowal Seed Farm were kept as untreated control, where no treatment was done. The data revealed higher rodent control success in conventional fields (71.26 %) followed by zero tillage (66.02%), maize (63.04%) residue and paddy residue (60.97%). Similarly, higher control success (on burrow count basis) was observed in conventional fields (88.88%) followed by zero tillage (72.72%), paddy residue (70.06%) and maize residue (67.64%) (Table 30). Per cent cut tillers in fields with residues of maize, paddy, zero tillage and conventional tillage were 1.22, 1.08, 0.74 and 0.62, respectively, being minimum in fields with conventional tillage. In control fields, per cent cut tillers ranged from 2.55 to 4.65. So, rodenticide treatment with burrow baiting at vegetative stage along with paper baiting at reproductive stage are must to control rodent pests in wheat crop sown with different residues in soil to increase yield of wheat crop.

Table 30. Per cent control success in wheat crop sown under different residues at Agronomy department, PAU campus, Ludhiana and treated with rodenticide baits

S. N	Crop type	Control success (%) (on plain bait consumption basis)	Control success (%) (on live burrow count basis)
1	Maize	63.04	67.64
2	Rice residue	60.97	70.06
3	Zero tillage	66.02	72.72
4	Conventiona l tillage	71.26	88.88

7.8. Rodent pest management in sugarcane crop as per the recommendation made at village Bhullarai

All the farmers of village Bhullarai (District Kapurthala) were made aware about the recommendation on rodent pest management in sugarcane crop. Rodenticide bait was distributed free of cost among farmers and all the sugarcane crop fields of the village were double poison baited first in the month of July and then in the month of November with 2% zinc phosphide bait followed by baiting with 0.005% bromadiolone both @400gm/acre at 15 days interval. Third poison baiting with 0.005% bromadiolone @ 800gm/acre was conducted in sugarcane crop fields with delayed harvesting in the month of January, 2014. Three fields of one acre each were selected from the village before each rodenticide treatment for record of pre and post-census bait consumptions. Based on these consumptions, control success was worked out. Results revealed that treatment in sugarcane fields at proper timings results in significant reduction in rodent damage to the crop. The control success was found to be highest (74.12%) after 3rd treatment of bromadiolone.

7.9. Comparison of acceptability of bait from different bait stations in rice crop

Comparison of acceptability of bait kept on pieces of paper and in PVC tubes and tyre bait stations in rice crop fields at Ladhowal Seed Farm of PAU revealed maximum acceptance of bait from paper bait stations. Bait consumption by rodents in wheat crop from tyre bait stations and paper bait stations was almost the same at village Noorpur Bet. Experiment conducted in rice crop at village Ghutani Kalan, district Ludhiana revealed n significant difference in per cent control success with poison baiting applied on paper bait stations (42.08%) and tyre bait stations (25.83%) thus suggesting the use of tyre bait stations in rainy weather.

7.10. Improvement in rodenticide bait application in sugarcane crop

An experiment was carried at village Ladhowal (distt Ludhiana) to determine the efficacy of 2% zinc phosphide when kept at the rate of 40, 20, 10, 5 and 1 bait points per acre. Results revealed no significant difference in control success and rodent damage among fields with 20, 10 and 5 bait points (Table 31). Consumption of poison

bait was low when kept at 1 point/acre. The control success in fields where 20 points were kept per acre, may be actually more than that observed, as in these fields whole of the pre-census bait (400g) was consumed. It may have been consumed more if kept more. So may be the original population be more than that observed.

Table 31. Improvement in rodenticide bait application in sugarcane crop

Blocks (n = 3 each)	**Bait points /acre**	**Bait consumption (g/400g bait) Mean ± SD**			**Control success**
		Pre-census	**Zinc**	**Post-census**	
I	40 @ 10g/spot	297.67±47.44	177.67±8.80	218.00±19.29	40.31%
II	20 @ 20g/spot	400.00±0.00	257.33±112.86	156.67±4.71	35.75%
III	10 @ 40g/spot	385.00±7.07	144.00±57.71	155.00±52.12	62.60%
IV	5 @ 80g/spot	352.00±9.93	180.33±70.26	140.00±8.16	60.23%
V	1 @ 80g/spot	217.67±72.34	6.00±5.89	128.33±15.45	41.04%

7.11. Rodent control in sugarcane using different methods of bait application

Four sugarcane blocks of 2 acres each were selected at village Ladhowal (distt Ludhiana). Block I was kept as untreated control. The empty gelatin based capsules were purchased from the marked and filled with freshly prepared 2% zinc phosphide bait. Blocks II, III and IV were treated with 2% zinc phosphide bait filled capsules applied by broadcasting (32 capsules per acre), 2% zinc phosphide bait on paper (16 points per acre) and 2% zinc phosphide bait filled capsules by burrow baiting (2 capsules per burrow), respectively. Burrow counting in each block was done both before and after treatment. Results revealed more percent rodent control success in fields treated with zinc phosphide by keeping bait on pieces of paper (75%) than by other methods of poison bait application (50-69.4%). Similar experiment was also conducted at village Dhanansu (district Ludhiana). The method of applying zinc phosphide bait in the capsules in burrows was found to be more appropriate than when zinc phosphide bait was kept on paper as indicated by higher control success (59.10 and 52.26%, respectively). The method when capsules containing zinc phosphide bait was broadcasted also gave good results having control success of 45.29%.

7.12. Evaluation of acceptance and efficacy of cement smeared on chapatti

In response to the feed back received from a farmer on use of chappati pieces smeared with cement for rodent control, laboratory experiment was carried out by feeding fresh

chapatti pieces smeared with cement to the predominant field rat species, *B. bengalensis* in bi-choice with plain food. Results revealed average consumption of 13.8g/100g body weight of cemented chapatti pieces in 5 days. No mortality of rats was caused. Mean daily consumption of chapatti pieces smeared with cement per rat was 2.76g/100g bw out of the 20g offered to each rat. Placement of fresh chapatti pieces smeared with cement near rodent burrows in sugarcane crop field daily during evening time for four consecutive days revealed about 95% consumption of chapatti pieces but there was observed only 25% reduction in live burrows.

7.13. Multilocational experiment on rodent control in wheat crop sown under rice residue management

Wheat crop is grown by two methods in Punjab, one by conventional tillage method and other by Happy Seeder technology under rice residue management. To evaluate the critical timings of rodenticide baiting in wheat crops grown with these two methods, a multilocational experiments were conducted during the last three years at villages Maksudra and Ghutani Kalan in district Ludhiana, Badoshi Kalan and Sadhugarh in district Fatehgarh Sahib and village Mewa Singh Wala in district Kapurthala.

In the year 2012-13, three blocks of wheat crop fields were selected at two locations each. One block at each location was treated with live burrow baiting using 2% zinc phosphide bait during December. Second block at each location was treated with burrow baiting during December as well as with paper baiting using 0.005% bromadiolone in the month of February. Results (Table 32) revealed higher per cent control success in fields with double treatment (32.44-47.73%) as compared to those with single treatment (10.61-21.64%) thus indicating the need of double treatment to control rats in wheat crop sown under Happy seeder method. Per cent damage done by rodents in treated fields was lower than controls.

Table 32. Per cent control success and rodent damage in wheat crop sown with Happy Seeder in districts Ludhiana and Kapurthala in 2012-13

District	Treatment	Control success (%)	Rodent damage	
			Cut tillers (%)	Yield loss (kg/ha)
Ludhiana	Double treatment	47.73	0±0	0±0
	Single treatment	10.61	0±0	0±0
	Control	-	0.18±0.04	9.32±3.85
Kapurthala	Double treatment	32.44	0.03±0.02	3.92±3.21
	Single treatment	21.64	0.00±0.00	0.00±0.00
	Control	-	0.22±0.03	19.61±3.20

In the year 2013-14, four blocks of wheat crop fields were selected at two locations each. One block at each location was treated with live burrow baiting using 2% zinc phosphide bait during December. Second block at each location was treated with paper baiting using 0.005% bromadiolone in the month of February and third block was treated both by burrow baiting during December as well as with paper baiting in February. Fourth block was kept as control. Results (Table 33) revealed higher per cent control success in fields with double treatment (44.37-73.43%) as compared to those with single treatment in February (16.27-27.30%) and single treatment in December (48.92-59.29%). Low percent control success with single treatment in February indicate that treating fields of wheat crop sown with Happy Seeder during the month of February only is not sufficient.

Table 33. Rodent control success and rodent damage in wheat crop sown with Happy Seeder in districts Kapurthala and Fatehgarh Sahib during 2013-14

District	Treatment	Control success (%)	Damage after treatment at pre-harvest stage	
			Cut tillers (%)	Yield loss (Kg/ha)
Kapurthala	Single baiting in burrow	48.92	1.38±0.38	159.1±45.5
	Single baiting n paper	16.27	1.31±0.69	96.5±46.26
	Double baiting Burrow + paper	44.37	1.03±0.31	80.79±26.4
Fatehgarh Sahib	Single baiting in burrow	59.29	0.37 ± 0.08	17.6 ± 0.44
	Single baiting on paper	27.30	0.18 ±0.02	9.40 ± 0.08
	Double baiting Burrow + paper	73.43	0.18 ±0.03	9.65 ± 0.22

In the year 2014-15, again four blocks of wheat crop fields were selected in villages of district Kapurthala. One block at each location was treated with live burrow baiting using 2% zinc phosphide bait during December. Second block at each location was treated with paper baiting using 0.005% bromadiolone in the month of February and third block was treated both by burrow baiting during December as well as with paper baiting in February. Fourth block was kept as control. Results (Table 34) revealed almost equal per cent control success in fields with double treatment (63.82%) and single treatment in February (65.66%). There was a increase in activity in fields where

only burrow baiting was done in December. Low percent control success with single treatment in February indicate that treating fields of wheat crop sown with Happy Seeder during the month of February only is not sufficient.

Table 34. Rodent control success and rodent damage in wheat crop sown with Happy Seeder in district Kapurthala during 2014-15

Treatments	Control success (%)	Damage after treatment at pre-harvest stage	
		Cut tillers (%)	Yield loss (Kg/ha)
Single baiting in burrow	Increase in activity	3.11±0.66	189.20±41.21
Single baiting on paper	65.66	0.64±0.25	45.90±18.34
Double baiting Burrow + paper	63.82	1.09±0.31	67.50±21.02

8. SOCIAL ENGINEERING ACTIVITY ON RODENT PEST MANAGEMENT AS PARTICIPATORY ADAPTIVE RESEARCH IN ADOPTED VILLAGES

8.1. Transfer of technology in adopted villages

Three villages were selected during wheat and rice crop periods in district Kapurthala during 2012-13. These were categorized as (i) Maintenance area (Village Sarai Jatan), (ii) Neglected area (village Kolianwala) and (iii) Survey area (Village Barindpur). During 2013-14, three villages selected were categorized as (i) Maintenance area (Village Noorpur Bet), (ii) Neglected area (village Bagha Khurd) and (iii) Survey area (Village Khera Bet). During 2014-15, the villages selected were (i) maintenance area (village Haddon Bet), (ii) neglected area (village Kacha Machhiwara) and (iii) survey area (village Sherpur Bet).

In maintenance area, proper education and training was imparted to the farmers through lectures regarding rodent control technologies and precautions to be taken while preparation and application of poison bait in wheat crop. Field demonstration was given on poison bait application at farmer's field. Leaflets containing information regarding rodenticide bait preparation, timings of rodenticide application and precautions while preparing and using rodenticide baits were distributed among the farmers. Rodenticide bait was got prepared on the spot in front of farmers and 1 kg packets of bait were distributed among farmers on the basis of their land holdings which were then applied by all the farmers in their fields. The survey area was kept as reference area where neither education was provided nor rodenticide bait was distributed.

The opinion survey was also conducted in all the villages before providing education by distributing a well structured questionnaire among the farmers assembled at a common place in each selected village. Through this questionnaire, farmers were asked about their existing knowledge on rodent control, their general attitude towards rodents as pests, their damage including socio-economic problems and the rodent control practices being used by them such as the methods of rodent control, rodenticides being used, methods of rodenticide bait preparation and application, timings of rodent control, pre-baiting, poison baiting in adjacent vacant land or uncultivated area, how they dispose off the left over poison bait and dead rats, permanent bund reconstruction and habitat manipulation. They were also asked whether they perform rodent control operations collectively at village level or not. The data so collected was calculated as percentages. Bait census and rodent damage census was taken before and after treatment to determine the effect of treatment and education.

Survey of farmers before imparting education revealed that pre-existing knowledge of farmers, their general towards rodent pests and the rodent control practices being used by them were quite similar across villages. Farmers considered rodents to be the pests responsible for low to high damage in their crops and recognize the need for their control for which they purchase rodenticide from the market themselves and apply in their fields. Most of the farmers were aware of the advantages of rodent control. They also knew the importance of habitat manipulation and protection of natural predators of rats for their control. They were aware of the fact that zinc phosphide should be applied before damage starts and rodent control operations should be conducted collectively at village level. Rodent control technologies commonly adopted among farmers include killing of the rodents coming out of the water filled burrows during irrigation and chemical control using zinc phosphide as rodenticide but they were not doing pre-baiting before using rodenticide bait and were using low dose of rodenticide in the poison bait, which was not sufficient to kill rodents resulting in development of bait shyness among rodents. Farmers were not much aware about the use of bromadiolone. However, some farmers were using bromadiolone cakes available in market in their houses.

Survey of farmers was again conducted during rice crop period to see the impact of education. After education, farmers started using both zinc phosphide and bromadiolone bait alternatively for control of rodents by preparing rodenticide baits as per the recommended method (Table 35). They applied rodenticides before grain filling stage rather than after looking at the damage. They started doing pre-baiting before using zinc phosphide and collected dead rats and left over poison bait for burrying them deep in the soil. Farmers applied control measures collectively in both cultivated and uncultivated areas.

Table 35. KAP analysis of farmers regarding rodent control practices

Sr. No.	Rodent control practices	Percent farmers			
		Maintenance village		Neglected village	
		Before	After	Before	After
1.	Controlling rats is important	88	100	82	100
2.	Adoption of rodent control	64.7	100	78	100
3.	Self application of rodenticides	85	100	95	100
4.	Prophylactic control	25	75	34	76
5.	Symptomatic control	75	25	66	34
6.	Pre-baiting before zinc phosphide	35	75	43	73
7.	Using only zinc phosphide	100	70	90	50
8.	Using both zinc phosphide and bromadiolone	0	30	10	50
9.	Using recommended dose rodenticides	40	100	50	100
10.	Collecting dead rats	10	50	10	40

8.2. Transfer of technology in modes other than villages of adoption

Rodent control technology was transferred to the end users by different modes like through TV/radio talks, training camps, field/office visits, kisan melas, extension workshops, lectures in various training programmes etc. which are given in Table 36.

Table 36. Extension activities on rodent pest management

i) Technical Guidance through Farm/Home/Field visits

Sr. No	Problem tackled	In office (No. of farmers)	In field visit (No. of farmers)	On telephone/ mobile
1	Provided individual level guidance on 'Management of squirrel in bajra crop' sown in PAU campus to a PG student from department of Agronomy while his visit in the office and my visit to the field.	-	One	May, 2012
2	Provided individual level guidance on 'Management of squirrel in garden area' near Shastri Nagar, Ludhiana having vegetable crops	-	One	12.06.12

	and fruit trees to the owner while his visit in the office			
3	Provided individual level guidance on 'Management of rats in a residential house near Model Town, Ludhiana to the owner while his visit in the office	-	One	29.06.12
4	Individual guidance on rodent pest management in kinnow orchard was provided to the owner of the orchard telephonically and through my official visits to the village Baryana, Distt Hoshiarpur	KVK Fatehgarh Sahib	One	24.07.12 and 26.07.12
5	Provided technical guidance on control of rodents in field crops to scientists at Borlaug Institute for South Asia, Ladhowal, Ludhiana, during 2014-2015	--	Scientists and field staff	--
6	Provided technical guidance to the owner and employees of poultry farm at village Naudharani, Malerkotla, District Sangrur on rodent proof measures needed at specific places in the poultry farm as per the request of the farmer through telephonic conversation and visit in November, 2014.	--	Owner and employees	--
7	Young farmers from Fazilka were given expert guidance for rodent damage in store houses and in paddy crop while their visit in the office on 18.05.15.	2	--	--
8	Provided technical guidance to employees of KRBL Limited Rice Mill, Village Bhasaur, Dhuri, Distt Sangrur for managing rodent pests as per their request and visit to the office. Personally visited the mill for on 19.05.15 for on the site evaluation of drawbacks and suggestion of remedial measures.	--	Employees	--
9	Provided technical guidance to a resident from Feroz Gandhi Market, Ludhiana on rodent control through telephonic conversation on 21.06.15.	--	--	1
10	Provided technical guidance to farmers visiting PAU Kisan Mela during Question/Answer session and on stall on 'Rodent Control'	Thousands of farmers visiting	--	--

		for kisan mela		
11	Provided technical guidance regarding rodent control to technical staff in Pal auditorium, PAU on 20-04-2015 and School of business studies on 18-11-2014.	Technical staff	--	--
12	Provided technical guidance regarding rodent control in department of Soil & Water Engineering, Department of Agronomy in fields for wheat, pea and sugarcane crops In January 2015; fields of dept. of Soil Science and dept. of Plant Breeding in November 2014	--	Technical staff and scientists	--
13	Provided technical guidance regarding rodent control in paddy crop to a farmer from village Nasib Khurd, Distt Moga on 17-07-2015.	--	--	1
14	Individual consultation provided on rodent pest management in residential area.	-	-	Time to time
15	Providing an expert guidance on rodent control to the officials/scientists of PAU/ GADVASU, Ludhiana.	-	-	Time to time

ii) Exhibitions organized

Sr. No	Particulars of Exhibition	Name of the event	Place of Exhibition	Products exhibition
1.	Rodent pest management	Kisan mela	21-22 Sep, 2012 at PAU, Ludhiana	Different species of rodents, rodent damage to different crops, traps, rodenticide baits and control methods for rodents.
2.	Rodent pest management	Kisan mela	15-16 Mar, 2013 at PAU, Ludhiana	-do-

3.	Rodent pest management	Kisan mela	13-14 September, 2013 at PAU, Ludhiana	-do-
4.	Rodent pest management	Research and Extension Specialists' Workshop for Kharif crops.	24 Feb, 2014 at PAU, Ludhiana	Charts, live specimens and model
5.	Rodent pest management	Kisan mela	14-15 March, 2014 at PAU, Ludhiana	Different species of rodents, rodent damage to different crops, traps, rodenticide baits and control methods for rodents.
6.	Rodent pest management	Research and Extension Specialists' Workshop for Kharif crops.	16 Feb, 2015 at PAU, Ludhiana	Charts, live specimens and model
7.	Rodent pest management	Kisan mela	12-13 September, 2014 at PAU, Ludhiana	Different species of rodents, rodent damage to different crops, traps, rodenticide baits and control methods for rodents.
8	Rodent pest management	Kisan mela	20-21 March, 2015 at PAU, Ludhiana	-do-

iii) TV/Radio talks delivered

Sr. No	Topic	Name of Expert	Date of Recording/Telecast/Broadcast
1.	Control of rats in wheat crop sown with Happy Seeder	Dr. Neena Singla	TV talk on 27.05.2013 in Mera Pind Mere Khet' programme of DD Jalandhar
2.	Control of rodents	Dr. B.K. Babbar	Rafio talk on 19.06.2013 in 'Dehati' Programme of Akashbani Jalandhar
3.	Rodent pest species, their damages and control methods	Dr. B.K. Babbar	TV talk on 13.09.2014 in Sunheri Dharti programme of Zee Punjabi
4.	Rodent control in wheat crop	Dr. Neena Singla	TV talk on 20.02.2015 in Kheti Khabran of DD Jalandhar
5.	Rodent control in field crops	Dr. Neena Singla	TV talk on 22.02.2015 in Mera Pind Mere Khet of DD Jalandhar
6.	Information on rodent control displayed at stall during kisan mela for farmers	Dr. Neena Singla	Radio talk on 20.03.2015 at All India Radio
7.	Garmi rutt diyan faslan vich chuhian di roktham	Dr. R. Singh	Radio talk on 04.05.2015 at Akashbani Jalandhar

iv) Demonstrations /antirat campaigns organized (Whole village)

Sr. No	Name of the Campaign	Place of Campaign
1	Ant-rat campaign in summer crops on 31.05.2013	Pindi, block Fatehgarh Choorian, district Gurdaspur
2	Anti-rat campaign in wheat crop on 21.11.2013.	Bhagvanpur, Distt Kapurthala
3	Anti-rat campaign in paddy crop on 25-07-2014.	Village Patara, Distt Jalandhar

4	Anti-rat campaign in wheat crop on 12-11-2014.	Village Macchiburga, Distt Ferozpur
5	Anti-rat campaign in wheat crop on 05-12-2014.	Village Partabpura, Distt Jalandhar
6	Anti-rat campaign in wheat crop on 18-03-2015.	Village Rattuwal, Distt Ludhiana
7	Anti-rat campaign in wheat crop on 18-03-2015.	Village Abbuwal, Distt Ludhiana

v) Trainings organized:

S. No.	Name of the programme	Date (s)	Participants
1.	Laboratory and field Demonstration during 7-days National training programme on 'Rodent Pest Management' State Agril. Officers in collaboration with NIPHM Hyderabad	16-22 April, 2013	20 participants from Punjab, Haryana and Himachal Pradesh
2.	One day training programme on 'Rodent Pest Management' in association with Directorate of Extension Education at PAU, Ludhiana	30.07.2013	12 participants among KVK scientists

vii) Expert lectures delivered

S. No.	Title of lecture	Organizing agency	Participants	Date(s)/ Scientist
1	Rodent control in rice crop	KVK Fatehgarh Sahib	Farmers (village Rajindergarh, Distt Fatehgarh Sahib)	Dr N. Singla 14.08.12
2	Rodent control in wheat crop sown with Happy Seeder	Directorate of Extension Education at PAU, Ludhiana	Kisan club members	Dr N. Singla 04.10.12
3	On farm rodent Control	PAMITI, PAU, Ludhiana	Newly recruited ADO's	Dr N. Singla 26.03.13 and 03.05.13
4	*Murgi farm te chuhiyan de roktham (In Punjabi)*	Department of Veterinary and Animal Husbandry Education, GADVASU	Farmers	Dr N. Singla (Total six in number)

5	Rodent control methods	IGMRI, PAU Campus	Food Supply officers from Punjab, Haryana and Himachal Pradesh	Dr N. Singla (Total 12 in number)
6	Advances in Rodent Pest Management	National Institute of Biotic Stress Management (NIBSM), IGKV Campus, Raipur	Extension functionaries of Chhattisgarh	Dr N. Singla 02 &3.08.14 (Total 4 in number)
7	Rodent control at post harvest stage	Directorate of Extension Education at PAU, Ludhiana	FCI officers of category II &III	Dr N. Singla (31 Nos.)
8	Rodent control at post harvest stage	Directorate of Extension Education at PAU, Ludhiana	FCI officers of category II &III	Dr B. K. Babbar (11Nos)
9	Lecture and field demonstration 'Rodents and their control'	Directorate of Extension Education at PAU, Ludhiana	To the Young trainees Farmers (38 trainees of 112th batch)	Dr N. Singla Dr. B.K. Babbar Feb 11-13, 2015

9. STUDIES ON PREDATORY POTENTIAL OF BARN OWLS AND ITS UTILIZATION FOR BIO-CONTROL OF RODENT PESTS.

The regurgitated pellets of Spotted Owlet were collected from their roosting, nesting and perching sites at different locations such as Post mortem building, New orchard, New area, Mushroom Farm and near Soil department at PAU campus, Naraiangarh Seed Farm of PAU, villages Mannewal, Bhudri and Chahar, district Ludhiana. Pellets were kept at 60°C in a hot air oven for 24 hours to kill the associated invertebrates. The weight, length, breadth and width of pellets collected were recorded.

Each pellet was soaked in 8% NaOH solution for about 2 hours to dissolve the hair and debris as described by Neelanarayan *et al* 1998. This solution (8% NaOH) assisted in easy separation of the remains (all skulls, cranial bones) and chitinous contents (undigested insect remains) from other contents like hair, debris etc. Then the contents were sieved to separate all the prey remains from the dust and soil particles. Later on, they were sorted out into different orders, type and number of bones of prey.

The identification of the small mammalian representatives in the diet of barn owl up to the species level was made by using the keys developed by Neelanarayan *et al* 1998. In the absence of mandibles, other bones like, skulls, limb bones, pectoral and pelvic girdles and synsacra (in the case of birds) were useful, especially for identification and quantifying the mammals (rodents, mouse, shrew and bat). Identification of small mammals were also done using bone sorting chart.

A total of 200 pellets of Spotted Owlet were collected from eight different locations. The majority of bones found were of *Mus* pp. in addition to few bones of

frogs, and birds. Body parts of insects were also found in thee pellets. The data on total number of bones found in the pellets is given in Table 37. Study reveals the potential of Spotted Owlet in controlling mouse population.

Five Barn Owls (3 mature and 2 young ones) were observed in wheat straw stored at village Mannewal (distt Ludhiana). Discussion with farmers revealed that these owls were living at that place for many years. Survey for rodent infestation in the area nearby the store and up to 1 km away from the area revealed the presence of burrows of *B. bengalensis* and *T. indica.* Regurgitated pellets of barn owl (n=43) were collected for analysis of prey species consumed. Barn owls were also seen in an orchard at Ladhowal Seed Farm of PAU but only two regurgitated pellets could be collected from orchard. A pair of Barn Owls was also observed in an old traditional store house at Ladhowal Seed Farm with their regurgitated pellets spread on the floor. Five Pariah Kite pellets were collected from an area near poultry farm in GADVASU, Ludhiana.

Table 37. Bones of different vertebrate prey items found in regurgitated pellets of Spotted Owlet

Bones	***Mus* spp.**	**Frog**	**Bird**
Skull	10		
Dislocated bones of skull	351		
Lower jaw (mandible)	204		
Ribs	271		
Shoulder blade	37		
Fore Limbs			
Humerus	177		1
Radius	138		
Ulna	156		
Hip bone	193		
Hind Limbs			
Femur	311	3	3
Tibia	299	3	
Fibula	42		
Vertebrae			
Atlas	20		

Axis	8		
Cervical	10		
Thoracic	23		
Lumber	67		
Sacral	23		
Caudal	224		
Hand/Foot Bones	288		
Patella	9		

10. STUDIES ON ZOONOSIS IN RELATION TO RODENT POPULATION OUTBREAK AND CROP HARVEST SEASONS.

The house rat, *R. rattus* is the predominant rodent pest species found throughout India. In addition to causing huge losses to food grains, it is also a major source of transmission of parasitic infections to humans. A total of 28, *R. rattus* were dissected and observed for parasitic infection. The liver of four (14.3%) rats was found having whitish cysts of *Cysticercus fasciolaris*, a metacestode of *Taenia taeniaeformis*. Yellowish streaks were present on the liver of two (7.1%) rats which were later identified to be due to infestation of *Capillaria hepatica*, a nematode parasite of zoonotic importance. From the intestine of one rat, adult cestode worm of *Hymenolepis diminuta* was recovered, which is also a parasite of zoonotic importance. From intestine of another rat, a nematode parasite of species *Trichuris muris* was also found.

In another study, out of the eighteen mature male *B. bengalensis* autopsied, livers of eight rats (44.4 %) were found infected with parasites comprising two (11.1 %) rats infected with *C. hepatica* alone and two (11.1 %) infected with *C. hepatica* in concurrence with *C. fasciolaris*. Gross lesions comprising of pale cystic areas or streaks on the surface of liver in rats revealed the presence of eggs of *C. hepatica* scattered in the parenchyma of the liver. Histologically, granulomatous reaction around the eggs, adult worms and dead components of parasites were observed. Keeping in view the great potential of adult female *C. hepatica* worms for production of large number of eggs and their zoonotic importance, it is necessary to prevent the incidence of this disease by taking proper sanitation and rodent control measures around animal and human dwellings.

Autopsy of 52 mature male *B. bengalensis* and 31 mature female *B. bengalensis* trapped from premises near railway station and agriculture fields at Ludhiana revealed lesions comprising pale cystic areas or streaks randomly scattered on the surface of the liver along with whitish cysts on or around the liver, helminthic worms in intestine were found in some rats. The parasites found in rats were cysts of *Cysticercus fasciolaris* in

liver, *Capillaria hepatica* in liver and *Hymenolepis diminuta* in intestine. Mixed infections with *C. fasciolaris* and *H. diminuta* along with enlarged spleen, infection with *C. fasciolaris* along with enlarged spleen and mixed infection with *C. hepatica* and *H. diminuta* were also observed (Table 38). The weight of epididymis in male rats and the weight of ovary in female rats infected with parasites were found to be significantly low from that of uninfected rats indicating some effect on reproduction. Potential of these parasites in affecting reproduction of rats can thus be explored.

Table 38. Various parasites and deformities found in *B. bengalensis*

Sex	No. infected /total	Infected (%)	Parasites found and deformity	Animals infected	Percentage of infected individuals	Percentage of total individuals
Male rats	35/52	67.31	*C. fasciolaris*	11	31.43	21.15
			C. hepatica	8	22.86	15.38
			Mixed infection *	9	25.71	17.31
			Mixed infection!	2	5.71	3.85
			Mixed infection #	1	2.86	1.92
			H. diminuta	3	8.57	5.77
			Enlarge spleen	1	2.86	1.92
Female rats	23/31	74.19	*C. fasciolaris*	6	26.09	19.35
			C. hepatica	5	21.74	16.13
			Mixed infection*	8	34.78	25.81
			Mixed infection ≠	2	8.70	6.45
			Mixed infection €	1	4.35	3.23
			Mixed infection ¥	1	4.35	3.23

**Mixed infection with C. fasciolaris and H diminuta,! Mixed infection with C. hepatica and H. diminuta, # Mixed infection with C. fasciolaris, H. diminuta and enlarged spleen, ≠ Mixed infection with C. fasciolaris and enlarged spleen, € Mixed infection with C hepatica, H diminuta and enlarged spleen, ¥ Mixed infection with C. hepatica and enlarged spleen*

Location Specific:

(a) <u>Toxicology of existing rodenticides</u>: Earlier studies on toxicity of bromadiolone have revealed its oral LD_{50} value only against common rodent species like, house mouse, house rat and Norway rats however no reports exists on LD_{50} value for cereal based formulation of bromadiolone (0.005%). Present study was therefore carried out

to determine LD_{50} value of bromadiolone (0.005%) bait against *R. rattus*. Nine different doses of 0.005% bromadiolone bait i.e. 1, 2, 4, 6, 8, 10, 16, 32 and 64 g/100g bw were fed to nine different groups of male *R. rattus* whereas, six different doses of bromadiolone bait (2, 4, 8, 16, 32 and 64 g/100g bw) were fed to six different groups of female rats. These values corresponded to 0.5 to 32.0 mg/kg bw of active ingredient in male and 1.0 to 32.0 mg/kg bw of active ingredient in female rats.

The LD_{50} values of active ingredient were found to be 1.05 and 1.83 mg/kg bw with corresponding values of 2.10 and 3.67 g/100g bw for bromadiolone (0.005%) bait in male and female rats, respectively. Bromadiolone was hence somewhat more toxic to males than females or in other words the males were more susceptible to bromadiolone than females. Individual variations in both the sexes were also observed in days to death after bromadiolone ingestion (Table 39).

Table 39. Percentage mortality in male and female *R. rattus* after administration of different doses of bromadiolone

Body weight (g) (n = 5 each)	**Dose of 0.005% bromadiolone bait ingested (g/100g bw)**	**Mortality (%)**	
		Male rats	**Female rats**
169.80±15.40	1.0	0	-
169.60±18.30	2.0	80	40
169.60±31.19	4.0	100	60
169.60±12.99	6.0	80	-
169.80±21.03	8.0	60	40
169.80±23.88	10.0	100	-
152.40±25.30	16.0	100	60
142.60±22.70	32.0	100	100
129.60±18.17	64.0	100	100

Studies were also carried out to determine LD_{50} value based on single oral doses of 0.25% bromadiolone administered to male and female *R. rattus* through gastric gavage. Total five groups of male and female rats with 4-5 rats in each group were

given five different doses of bromadiolone (i.e. 0, 2, 4, 6 and 8 mg/kg bw). Rats were observed daily for toxicity and mortality. LD_{50} and LD_{99} values of bromadiolone for both male and female rats were determined through Probit Analysis using Polo software. The results are given in Table 40. Results revealed 75 to 100% mortality within 1-6 days of male rats and 40-100% mortality of female rats within 1-7 days. Females were found more tolerant to bromadiolone toxicity as compared to male rats. The LD_{50} and LD_{99} were found to be 1.88 and 2.33 mg/kg bw in male rats and 2.04 and 2.47 mg/kg bw in female rats.

Table 40. Toxicity of bromadiolone administered orally to male *R. rattus*

S. No.	Dose (mg/kg bw)	Mortality (%)		Days to death	
		Male rats	Female rats	Male rats	Female rats
1.	0	0	0	-	-
2.	2	75	40	3 days	2 days
3.	4	100	100	1-6 days	1-7 days
4.	6	100	100	2-5 days	3-7days
5.	8	100	100	1-3 days	2-3 days

(b) <u>Studies on development of ready to use bait of acute rodenticides</u>: Rodents quickly learn to avoid zinc phosphide poison bait due to its odour and taste. Therefore, there is a need to prepare zinc phosphide bait in such a way so that its odor and taste can be effectively masked. To avoid this, 2% zinc phosphide was microencapsulated using three different formulations. Each formulation was then mixed in cracked wheat and fed to three groups of *R. rattus* after recording their consumption of plain WSO bait. Consumption of bait containing formulation II was minimum (1.80) and that containing formulation III was maximum (2.40). Mortality of rats within 18 hours was 80% with bait containing formulations I and II while it was 100% with formulation III indicating better potential of formulation III as compared to that of formulation I & II.

When zinc phosphide toxicant is mixed with the bait, phosphine is generated before being eaten in required lethal quantities causing rejection of the bait by the rodent. Such liberation of phosphine gas after mixing the toxicant in baits can be substantially prevented by adding a metal salt to the bait. Further, it has been found that the effectiveness of the zinc phosphide can be enhanced significantly by incorporating into the bait a gastric juice stimulant. The purpose of such stimulant is to increase the acid concentration in the rodent's stomach and thereby promoting the release of the phosphine gas. Keeping above points in view, three formulations of 2% zinc phosphide

bait were prepared. Formulation I contained only zinc phosphide mixed in 2% WSO bait. Formulation II contained zinc phosphide and metal salt mixed in 2% WSO bait and formulation III contained zinc phosphide, metal salt and gastric juice stimulant mixed in 2% WSO bait. Each formulation was fed to three groups of *R. rattus* after recording their consumption of plain WSO bait. Results revealed reduced consumption of plain WSO bait during treatment period. No significant difference was there in consumption of different formulations, but the time to 100% mortality was minimum with formulation II and maximum with formulation I (Table 41). There is a need to further improve the method of preparation of zinc phosphide formulations to increase its effectiveness. Further experiments are under progress.

Table 41. Consumption and percent mortality of house rat *R. Rattus* with different formulations of zinc phosphide

Formulations of 2% zinc phosphide	**Body weight (g) (n =10 each)**	**Pre-census bait consumption (g/100g bw)**	**Consumption during treatment (g/100g bw)**		**Time to 100% mortality (hrs)**
			Plain bait	**Treated bait**	
Formulation I	79.20±1.36	13.57±2.12	2.42±0.70	3.25±0.62	23.87±11.40
Formulation II	83.80±2.79	10.38±1.71	2.42±0.72	2.83±0.39	14.27±4.90
Formulation III	81.80±2.14	14.43±1.87	3.71±0.52	3.00±0.64	18.25±3.16

(c) Behavioural studies on predominant rodent species

i) Study of repellent behavior of *R. rattus* in response to formulations of cinnamic aldehyde and cinnamamide: Exposure of *R. rattus* of both sexes in I-maze to effective formulation II (prepared by mixing 5% cinnamic aldehyde and 1% $NaHCO_3$ in water) of cinnamic aldehyde in bi-choice with plain bait revealed no significant difference between the two sexes. There was also no significant difference in zone frequency, total distance moved (cm), frequency of rearing and frequency of mobility between untreated and treated zones but values of all the parameters were lower in treated zone as compared to untreated zone indicating reduced activity of rats in treated zone in response to formulation II (Table 42).

Exposure of *R. rattus* of both sexes in I-maze to effective formulation III (prepared by mixing 0.4 g cinnamamide dissolved in 25 ml methanol and 1g $NaHC0_3$ dissolved in 25 ml water) of cinnamamide also revealed no significant difference between the two sexes. There was also no significant difference in zone frequency, total distance moved (cm), frequency of rearing and frequency of mobility between untreated and treated zones but values of all the parameters were lower in treated zone as compared to untreated zone indicating reduced activity of rats in treated zone in response to formulation III of cinnamamide (Table 43).

Table 42. Repellent behaviour of *Rattus rattus* in response to formulation II of cinnamic aldehyde in I-Maze under bi-choice condition

S. No.	Parameter	Treatment/days	Untreated Zone (n = 6)	Treated Zone (n = 6)
1.	In zone frequency	Pre treatment	171.22±102.07	79.84±31.39
		Day 1 Treatment	40.00±20.02	43.83±16.52
		Day 2 Treatment	67.33±40.99	21.83±8.75
		Day 3 Treatment	41.50±15.97	32.00±15.82
		Post Treatment	151.00±96.72	44.94±29.16
2.	Total distance moved (cm)	Pre treatment	6117.39±2300.92	6162.90±2016.62
		Day 1 Treatment	18013.12±2115.97	6087.65±932.33
		Day 2 Treatment	15107.82±5865.88	4302.62±1609.67
		Day 3 Treatment	12473.99±5541.12	3915.65±157.98
		Post Treatment	93769.15±2523.34	4331.93±1796.90
3.	Frequency of rearing	Pre treatment	369.50±157.72	754.11±79.29
		Day 1 Treatment	1009.50±123.86	549.00±203.17
		Day 2 Treatment	1411.50±513.94	367.00±158.86
		Day 3 Treatment	1326.00±664.91	268.00±46.90
		Post Treatment	532.33±212.84	334.88±125.78
4.	Frequency of mobility	Pre treatment	599.37±254.46	944.08± 256.20
		Day 1 Treatment	857.00±250.32	726.50±265.52
		Day 2 Treatment	1760.00±640.16	502.50±223.79

		Day 3 Treatment	1848.16±633.53	286.16±134.06
		Post Treatment	707.16±263.32	461.38±223.85

ii) Study of antifeedant behavior of *R. rattus* in response to formulations of cinnamic aldehyde and cinnamamide: Antifeedant behaviour of *R. rattus* of both sexes towards formulation II of cannamic aldehyde and formulation III of cinnamamide was recorded using Feed Scale Consumption Monitor (FSCM). Results revealed a non-significant difference in number of feeding bouts, feeding bout length and feed consumed (g) between both the sexes but there was a significant reduction ($P \leq 0.05$) in the values of all the three parameters during treatment period as compared to pre-treatment period (Tables 44-45).

Table 43. Repellent behaviour of *Rattus rattus* in response to formulation III of cinnamamide under bi-choice condition in I-Maze

S. No.	Parameter	Treatment/days	Untreated Zone (n = 6)	Treated Zone (n = 6)
1.	In zone frequency	Pre treatment	171.22±102.07	79.84±31.39
		Day 1 Treatment	53.00±26.86	44.00±28.24
		Day 2 Treatment	20.13±6.66	35.83±20.10
		Day 3 Treatment	13.16±6.78	41.60±0.86
		Post Treatment	151.00±96.72	44.94±29.16
2.	Total distance moved (cm)	Pre treatment	6117.39±2300.92	6162.90±2016.62
		Day 1 Treatment	21070.62±11812.94	16216.70±7795.22
		Day 2 Treatment	26533.48±5586.58	3141.05±1112.27
		Day 3 Treatment	21526.59±7555.37	1571.15±1085.44
		Post Treatment	93769.15±2523.34	4331.93±1796.90
3.	Frequency of rearing	Pre treatment	369.50±157.72	754.11±79.29
		Day 1 Treatment	1009.50±123.86	549.00±203.17
		Day 2 Treatment	1411.50±513.94	367.00±158.86
		Day 3 Treatment	1326.00±664.91	268.00±46.90
		Post Treatment	532.33±212.84	334.88±125.78

4.	**Frequency of mobility**	Pre treatment	599.37±254.46	944.08±256.20
		Day 1 Treatment	1511.83±752.92	1316.33±599.73
		Day 2 Treatment	2234.33±539.32	279.16±102.28
		Day 3 Treatment	2098.50±661.81	128.50±86.66
		Post Treatment	707.16±263.32	461.38±223.85

iii) Study of repellent behavior of *B. bengalensis* in response to formulation II of cinnamic aldehyde: Behaviour of *B. bengalensis* was recorded in response to repellent property of formulation II of cinnamic aldehyde (5%) containing sodium bicarbonate as emulsifier and tert-butyl hyroxyquionone as photostabilizer in bi-choice condition in I-maze under camera operated ethovision video tracking system. Results revealed reduction in values of all parameters in treated zone as compared to untreated zone and central untreated hub indicating repellent property of cinnamic aldehyde (Table 46).

iv) Study of antifeedant behavior of *B. bengalensis* in response to formulation II of cinnamic aldehyde: Feeding behaviour of *B. bengalensis* was also recorded under Feed scale consumption monitor in response to antifeedant property of formulation II of cinnamic aldehyde. Results revealed a no significant difference in number of feeding bouts, feeding bout time and feed consumed between the two sexes but there was a significant reduction in the values of all the three parameters during treatment period as compared to pre-treatment period. Rats did not find the compound immediately repellent, consumption of treated bait declined almost completely after day 1 in both male and female rats and remained almost nil for the rest of the treatment period (Table 47). The response of bandicoot rats to cinnamic aldehyde is indicative of learned aversion.

Table 44. Antifeedant behavior of *Rattus rattus* in response to formulation II of cinnamic aldehyde in feed scale consumption monitor

Sex	**Days**	**Pre-treatment period***			**Treatment period****			**Antifeedant Index (%)**
		Number of feeding bouts	**Feeding bout length (sec)**	**Feed consumed (g)**	**Number of feeding bouts**	**Feeding bout length (sec)**	**Feed consumed (g)**	
Male#	Day 1	6.33±2.12	327± 134.77	0.72± 0.3	0.67± 0.18	15±6.34	0.15±0.11	87.92± 8.32
	Day 2	17.67±11.57	543± 354.61	1.07± 0.69	2.67± 1.18	123.33 ± 50.67	0.29±0.12	73.46± 16.89

	Day 3	10.33± 7.22	580± 371.34	1.33± 0.62	4±1.88	227.33 ± 110.69	0.74±0. 41	76.63± 12.11
	Day 4	8.33± 3.21	405.33± 108.96	1.67± 0.54	1±0.82	15±12. 24	0.04±0. 03	98.4± 1.30
	Day 5	8.67± 2.33	455.33± 160.75	1.7± 0.42	0	0	0	100±0
	Day 6	21.33± 4.45	537.67± 169.51	2.07± 0.38	0.33± 0.27	9±7.35	0.01± 0.08	99.64± 0.28
Femal e[#]	Day 1	4±0.47	456.66± 50.40	0.64± 0.11	2.67± 1.78	106± 81.29	0.49± 0.23	33.33± 27.22
	Day 2	8±2.49	483±65. 64	3.33± 0.82	3.33± 2.72	109± 88.99	0.62± 0.51	81.77±14. 88
	Day 3	10.67± 1.78	557.66± 189.44	2.45± 0.60	2.67± 1.78	90.67± 44.92	0.56± 0.38	66.13±25. 37
	Day 4	11.67± 2.68	665.66± 95.15	2.28± 0.85	2.33± 1.51	98.67± 59.88	0.79± 0.40	65.96± 22.87
	Day 5	11.67± 1.65	522± 186.23	2.86± 1.3	2±1.25	48± 32.89	0.31± 0.24	69.90± 24.43
	Day 6	8.67± 3.34	430.67± 229.35	3.91± 2.27	0.33± 0.27	4.67± 3.81	0.02± 0.02	97.75± 1.83

Values are Mean±SE

**, ** In overall, significant difference between pre-treatment and treatment periods*

 # In overall, non-significant difference between male and female rats

Table 45. Antifeedant behavior of *Rattus rattus* in response to formulation III of cinnamamide in Feed Scale Consumption Monitor

Sex	Days	Pre-treatment period*			Treatment period**		
		Feeding bout events	Feeding bout time (sec)	Feeding (g)	Feeding bout events	Feeding Bout time (sec)	Feeding (g)
Male*	Day 1	6.33±2.12	327±134.77	0.72±0.3	3± 1.41	85±49.03	0.74± 0.37
	Day 2	17.67±11.57	543±354.61	1.07±0.69	1± 0.82	5±4.08	0.01± 0.00
	Day 3	10.33±7.22	580±371.34	1.33±0.62	1±0.47	5±2.05	0.02±0.01
	Day 4	8.33±3.21	405.33±108.96	1.67±0.54	0.66±0.27	4.33±1.78	0.05±0.02
	Day 5	8.67±2.33	455.33±160.75	1.7±0.42	0	0	0
	Day 6	21.33±4.45	537.67±169.51	2.07±0.38	0	0	0
Female*	Day 1	4±0.47	456.66±50.40	0.64±0.11	3±2.44	89.66±73.21	0.66±0.53
	Day 2	8±2.49	483±65.64	3.33±0.82	1.33±0.72	23±13.14	0.17±0.07
	Day 3	10.67±1.78	557.66±189.44	2.45±0.60	0	0	0
	Day 4	11.67±2.68	665.66±95.15	2.28±0.85	2.66±2.17	104±84.92	0.04±0.02
	Day 5	11.67±1.65	522±186.23	2.86±1.3	0.33±0.27	8±6.53	0.13±0.10
	Day 6	8.67±3.34	430.67±229.35	3.91±2.27	0.33±0.27	4.66±3.81	0.02±0.01

**, ** In overall, significant difference in food consumption from untreated and treated side*

Table 46. Repellent behaviour of *B. bengalensis* in response to formulation II of cinnamic aldehyde in I-Maze under bi-choice condition

S. No.	Parameter	Movements of rats (n=6)		
		Treated zone	Untreated Zone (central hub)	Untreated Zone
1.	In zone frequency	3.50±0.87[a]	8.10±2.12 [b]	5.60±2.28 [c]
2.	In zone total duration (sec)	44.90±8.69[a]	121.50±44.90[b]	5003.50±1032.40[c]
3.	Total distance moved (cm)	5.26±1.59[a]	2655.20±2162.50[b]	5439.60±4806.90[c]
4.	Mean velocity	4.80±0.97 [a]	4.50±0.89[b]	4.17±0.45 [c]
5.	Rearing frequency	5.16±1.81[a]	9.90±2.99[b]	883.40±366.90[c]
6.	Mobility	2.23±0.70[a]	6.40±5.73[b]	1782.00±1061.60[c]

Table 47. Behavior of *B. bengalensis* in response to antifeedant property of formulation II of cinnamic aldehyde in feed scale consumption monitor

Sex	Days	Pre-treatment period*			Treatment period**		
		Number of feeding bouts	Feeding bout time (sec)	Feed consumed (g)	Number of feeding bouts	Feeding bout time (sec)	Feed consumed (g)
Male	Day 1	5.83± 0.36	177.00± 145.06	4.59±0.71	0.66± 0.54	11.00± 1.24	0.04±0.01
	Day 2	3.33± 1.13	37.50±17.01	2.46±0.29	0	0	0
	Day 3	2.00± 0.81	61.30±50.07	3.22±0.50	2.00± 0.47	11.60± 2.35	0.02±0.01
Female	Day 1	2.33± 0.41	269.80±183.7	4.00±0.45	1.00±0.4	16.00± 1.9	0.11±0.04
	Day 2	6.33± 1.78	293.80±120.9	4.84±0.19	0	0	0
	Day 3	8.83± 6.40	157.00±115.6	4.03±0.90	0	0	0

Values are Mean±SE

, show significant difference between pre-treatment and treatment periods at p≤0.05*

v) Repellent behaviour of *R. rattus* in response to 5% eucalyptus and 5% citronella oils in multi-choice feeding test: Record of behaviour of male and female *R. rattus* in response to 5% eucalyptus and 5% citronella oils kept as encapsulated wax blocks in multi-choice test in T-maze revealed significantly low values for total distance moved, maximum distance moved, mean velocity, frequency of rearing, frequency of mobility in zones treated with eucalyptus and citronella oils as compared to the untreated zones. The latency of first occurrence was more in the zone treated with eucalyptus oil than zone treated with citronella oil. The values of the other parameters recorded were more in the zone treated with citronella oil than zone treated with eucalyptus oil thus indicating prolonged repellent effect of 5% eucalyptus oil than citronella oil.

vi) Repellent behaviour of *R. rattus* in response to 5% eucalyptus oil in bi-choice feeding test: Behaviour of male and female *R. rattus* in response to 5% eucalyptus oil kept as encapsulated wax blocks in bi-choice condition in I-maze revealed no significant difference in in zone frequency, latency of first occurrence and mean velocity between untreated and treated zones. A significant difference was however found between the two zones for total and maximum distance moved, frequency of rearing and mobility. A significant difference was also found among the three replicated rats for total distance and maximum distance moved and in zone frequency. In zone frequency and total distance moved on day of no treatment were almost similar to those found on day 3rd of the treatment indicating reduced persistence of the repellent effect of the oil. The record of animal tracks in the maze revealed reduced movement and activity of the rats in treated zones. A significant difference was found in all the parameters recorded between untreated and treated with values of these parameters lower in treated zone. No significant difference was observed between the two sexes.

d) Evaluation of triptolide for antifertility effects against predominant rodents

i) Antifertility effects of triptolide in male *B. bengalensis*: Feeding of different concentrations of triptolide i.e. 0.15, 0.20 and 0.25% in bait to male *B. bengalensis* for 15 days duration in bi-choice feeding tests revealed significantly ($P \leq 0.05$) low consumption of treatment bait from that of untreated bait. Breeding of treated male rats with untreated cyclic female rats revealed no breeding in males treated with 0.2 and 0.25% triptolide. Autopsy of male rats immediately and after 30 and 60 days of treatment withdrawal revealed significant reduction in weights of reproductive organs; decrease in sperm motility, viability and density and increase in sperm abnormality in rats of treated groups (Tables 48-50). No effect of treatment was observed on plasma levels of male sex hormones, testosterone. The plasma levels of total proteins and enzymes were found increased significantly in all the treated groups of male rats. Histomorphology of testis revealed a significant decrease in diameter of seminiferous tubules and number of different germ cells indicating effect of triptolide on spermatogenesis and spermeiogenesis (Tables 51-52).

Table 48. Effect of triptolide treatment on weights of reproductive organs and cauda epididymal sperm parameters immediately after termination of treatment

Organ wt./sperm parameters	Treatment (n=5 each) (Mean±SEM)			
	0%	**0.15%**	**0.20%**	**0.25%**
Testis (g/100g bw)	0.34±0.04[a]	0.19±0.02[b]	0.19±0.01[b]	0.09±0.01[c]
Epididymis (g/100g bw)	0.08±0.007[a]	0.07±0.004[a]	0.06±0.004[a]	0.03±0.001[b]
Seminal vesicles (g/100g bw)	0.57±0.05[a]	0.54±0.07[a]	0.53±0.03[a]	0.24±0.003[b]
Prostate gland (g/100g bw)	0.32±0.03[a]	0.39±0.06[a]	0.28±0.04[a]	0.08±0.01[b]
Sperm motility (%)	69.70±1.94[a]	19.50±2.17[b]	17.20±3.93[bc]	3.50±0.94[c]
Sperm viability (%)	77.75±1.60[a]	36.70±0.97[b]	27.40±0.38[c]	18.78±1.37[d]
Sperm density (millions/ml)	365.00±13.93[a]	243.00±12.62[b]	177.00±13.01[c]	133.33±9.81[c]
Sperm head tail separation (%)	11.22±1.52[a]	20.88±2.27[b]	26.63±1.27[b]	54.06±3.14[c]
Other sperm abnormalities (%)	8.59±2.18[a]	21.07±1.96[b]	29.54±1.72[c]	34.00±1.33[c]

[a-c]Values with different superscripts in a row differ significantly at $P \leq 0.05$

Table 49. Effect of triptolide treatment on weights of reproductive organs and cauda epididymal sperm parameters after 30 days of termination of treatment

Organ wt./sperm parameters	Treatment (n=5 each) (Mean±SEM)			
	0%	**0.15%**	**0.20%**	**0.25%**
Testis (g/100g bw)	0.25±0.01[a]	0.17±0.02[b]	0.16±0.01[b]	0.09±0.02[c]
Epididymis (g/100g bw)	0.07±0.002[a]	0.05±0.008[b]	0.06±0.005[ab]	0.05±0.002[b]
Seminal vesicles (g/100g bw)	0.51±0.01[a]	0.38±0.11[a]	0.33±0.04[a]	0.33±0.01[a]
Prostate gland (g/100g bw)	0.34±0.01[a]	0.15±0.04[ab]	0.18±0.04[ab]	0.08±0.02[b]
Sperm motility (%)	66.60±0.81[a]	21.70±10.06[b]	8.88±2.53[b]	2.75±0.54[b]

Sperm viability (%)	72.65±1.22[a]	26.56±3.48[b]	22.95±2.00[b]	20.25±2.60[b]
Sperm density (millions/ml)	342.00±31.21[a]	226.00±25.55[b]	192.50±19.49[b]	158.75±8.17[b]
Sperm head tail separation (%)	9.40±1.92[a]	25.20±2.66[b]	40.23±0.42[c]	55.87±1.87[d]
Other sperm abnormalities (%)	4.71±0.79[a]	25.58±3.09[b]	29.92±1.25[b]	32.47±2.28[b]

[a,b]*Values with different superscripts in a row differ significantly at P ≤ 0.05*

Table 50. Effect of triptolide treatment on weights of reproductive organs and cauda epididymal sperm parameters after 60 days of termination of treatment

Organ wt./sperm parameters	**Treatment (n=5 each) (Mean±SEM)**			
	0%	**0.15%**	**0.20%**	**0.25%**
Testis (g/100g bw)	0.24±0.01[a]	0.21±0.03[b]	0.18±0.04 [b]	0.14±0.03 [b]
Epididymis (g/100g bw)	0.07±0.003[a]	0.06±0.006 [b]	0.06±0.01[ab]	0.05±0.01[b]
Seminal vesicles (g/100g bw)	0.50±0.01[a]	0.45±0.10[a]	0.41±0.06[a]	0.21±0.04[a]
Prostate gland (g/100g bw)	0.33±0.01[a]	0.24±0.05[a]	0.28±0.02[a]	0.09± 0. 01[b]
Sperm motility (%)	71.50±0.96[a]	22.70±8.32[b]	9.33±0.95[b]	3.13±1.34[b]
Sperm viability (%)	71.76±3011[a]	27.01±2.48[b]	23.73±0.97[b]	20.65±2.82[b]
Sperm density (millions/ml)	356.00±17.71[a]	240.00±18.60[b]	226.67±28.80[b] [c]	171.25±10.51[c]
Sperm head tail separation (%)	9.28±2.18[a]	22.51±1.82[b]	38.84±0.77[c]	51.27±2.04[d]
Other sperm abnormalities (%)	4.28±0.93[a]	22.60±1.11[b]	29.98±0.99[c]	36.73±0.87[d]

[a-c]*Values with different superscripts in a row differ significantly at P ≤ 0.05*

ii) Antifertility effects of triptolide in female *B. bengalensis*: Feeding of different concentrations of triptolide i.e. 0.10, 0.15 and 0.20% to female *B. bengalensis* for 15 days in bi-choice feeding tests revealed significantly low consumption of treated bait from that of untreated bait. Autopsy of female rats after 15 and 30 days of treatment withdrawal revealed increase in duration of estrous cycle in rats of treated groups (Table 53) and significant reduction in weights of ovary and uterus. No effect of treatment was observed on plasma levels of hormones. The plasma levels of total proteins and enzymes were found increased significantly in all the treated groups of female rats. Histomorphology of uterus and ovary revealed significant antifertility effects of triptolide (Tables 54-55). Study suggests use of triptolide in integration with chemical control for population regulation of *B. bengalensis*.

Table 51. Variations in the true count of cells and diameter of the seminiferous tubules of male *B. bengalensis* immediately after triptolide treatment

Treatment (n=5)	SG	L	Z	P	D	RS	EL	ED	SZ	SC	STD (mm)
0% (I)	5.43± 0.30^{a}	1.16± 0.49^{a}	6.95± 2.27^{a}	24.46± 3.12^{a}	12.91 ±4.17	51.63 ±6.49^{a}	17.74± 7.10^{a}	18.70± 7.50^{a}	24.30± 7.82^{a}	4.84± 0.25^{a}	0.19± 0.004^{a}
0.15% (II)	7.07± 0.17^{b}	0.60± 0.18^{a}	1.28± 0.60^{b}	17.42± 1.59^{ab}	2.56± 1.39^{b}	29.05± 2.92^{b}	4.20± 1.97^{b}	1.00± 0.98^{b}	8.83±3.05^{ab}	14.11± 1.12^{b}	0.17± 0.002^{b}
0.2% (III)	7.87± 0.38^{b}	0.32 ±0.15^{a}	1.28± 0.48^{b}	14.19± 1.63^{b}	3.56± 1.30^{b}	29.17± 3.35^{b}	3.68± 1.32^{b}	0.24± 0.23^{b}	0.00± 0.00^{b}	18.98± 0.66^{c}	0.17± 0.004^{b}
0.25% (IV)	9.31± 0.28^{c}	0.0± 0.00^{b}	0.0± 0.00^{b}	0.0± 0.00^{c}	0.0± 0.00^{b}	0.0± 0.00^{c}	0.0± 0.00^{c}	0.0± 0.00^{b}	0.0± 0.00^{b}	25.93± 0.58^{d}	0.14± 0.004^{c}

-Values are Mean±SEM, -Values with different superscripts in a column differ significantly $P \leq 0.05$.

Table 52. Variations in the true count of cells in seminiferous tubules of male *B. bengalensis* after 30 and 60 days of treatment withdrawal.

Cells	Cell count (n=5 each) (Mean ± SEM)						
		After 30 days of treatment withdrawal			After 60 days of treatment withdrawal		
	0%	0.15%	0.20%	0.25%	0.15%	0.20%	0.25%
SG	5.47±0.26^{a}	7.39±0.20^{b}	7.83±0.29^{b}	9.39±0.25^{c}	5.71±0.26^{a}	6.79±0.27^{b}	8.19±0.32^{c}
PL	0.68±0.28^{a}	0.44±0.14^{ab}	0.40±0.11^{ab}	0.00±0.00^{b}	0.44±0.17^{a}	0.44±0.13^{a}	0.08±0.05^{a}
L	1.20±0.43^{a}	0.44±0.16^{a}	0.40±0.14^{a}	0.00±0.00^{a}	0.52±0.18^{a}	0.44±0.15^{a}	0.08±0.08^{a}
Z	8.51±2.51^{a}	1.60±0.64^{b}	1.68±0.55^{b}	0.00±0.00^{b}	1.80±0.72^{b}	1.56±0.57^{b}	0.64±0.35^{b}
P	25.97±3.91^{a}	17.46±2.05^{ab}	13.11±1.82^{b}	0.00±0.00^{c}	20.26±2.08^{ab}	14.79±1.87^{b}	2.36±1.28^{c}
D	16.02±4.29^{a}	4.04±1.62^{b}	4.16±1.23^{b}	0.00±0.00^{b}	4.04±1.62^{b}	4.16±1.35^{b}	1.12±0.61^{b}
RS	50.31±7.56^{a}	30.29±3.36^{b}	25.73±3.57^{b}	0.00±0.00^{c}	33.97±3.45^{ab}	29.45±3.74^{b}	3.48±1.89^{c}
EL	18.40±6.56^{a}	4.52±2.09^{b}	4.36±1.29^{b}	0.00±0.00^{b}	4.60±2.13^{b}	4.44±1.61^{b}	0.00±0.00^{b}
ED	19.00±7.60^{a}	7.00±3.85^{ab}	1.52±1.49^{b}	0.00±0.00^{b}	10.36±4.76^{a}	7.68±3.53^{a}	0.00±0.00^{a}
SZ	23.72±8.45^{a}	8.24±3.80^{ab}	0.00±0.00^{b}	0.00±0.00^{b}	11.64±5.34^{ab}	0.00±0.00^{b}	0.00±0.00^{b}
SC	5.23±0.17^{a}	14.95±0.74^{b}	19.54±0.42^{c}	25.93±0.58^{d}	13.31±0.73^{b}	17.94±0.48^{c}	22.22±0.40^{d}
Total	174.53±7.96^{a}	96.38±4.78^{b}	78.75±2.70^{b}	35.35±0.57^{c}	106.65±6.32^{b}	87.70±3.97^{b}	36.43±3.31^{c}

^{a}Values with different superscripts (a-d) in a row after 30 and 60 days of treatment withdrawal differ significantly at $P \leq 0.05$ with respect to control group as well as treated groups

Table 53. Effects of triptolide on number and duration of estrous cycle

Conc. in bait (%)	No. of estrous cycles in 15 days period				Duration of one estrous cycle in 15 days period (days)			
	Before treatment (n=8 each)	During treatment (n=8 each)	With in 15 days after termination of treatment (n=8 each)	Within 15 to 30 days after termination of treatment (n =4 each)	Before treatment (n=8 each)	During treatment (n=8 each)	With in 15 days after termination of treatment (n=8 each)	Within 15 to 30 days after termination of treatment (n =4 each)
0.00	3.50 ± 0.20^{a}	3.33 ± 0.19^{a}	3.50 ± 0.20^{ab}	3.25 ± 0.22^{ab}	4.00 ± 0.33^{a}	4.17 ± 0.28^{a}	4.00 ± 0.33^{a}	4.25 ± 0.25^{a}
0.10	3.43 ± 0.19^{a}	3.14 ± 0.14^{a}	2.86 ± 0.13^{b}	3.00 ± 0.00^{ab}	4.29 ± 0.19^{a}	4.29 ± 0.14^{a}	5.43 ± 0.28^{b}	4.67 ± 0.24^{ab}
0.15	3.38 ± 0.17^{a}	2.63 ± 0.17^{bc}	2.38 ± 0.17^{c}	2.75 ± 0.22^{ac}	4.38 ± 0.25^{a}	4.50 ± 0.18^{a}	6.63 ± 0.30^{c}	5.25 ± 0.22^{ac}
0.20	3.50 ± 0.18^{a}	2.25 ± 0.15^{bc}	1.88 ± 0.08^{c}	2.50 ± 0.25^{bc}	4.25 ± 0.23^{a}	5.25 ± 0.15^{b}	8.00 ± 0.25^{d}	6.50 ± 0.56^{bcd}

-Values are Mean ± SE, Values with different superscripts (a-d) in a column as well as in a row for number of estrous cycles and duration of estrous cycles differ significantly at $P \leq 0.05$

Table 54. Effect triptolide treatment on follicular kinetics (normal follicles) in the ovaries of female *B. bengalensis*

Treatment/ group	Mean number of normal follicles						
	Primordial	**Primary**	**Secondary**	**Tertiary**	**Pre-antral**	**Antral**	**Corpus luteum**
0% (I)	17.33±0.54[a]	11.67±0.27[a]	8.00±0.47[a]	6.67±0.27[a]	5.33±0.27[a]	5.33±0.27[a]	9.67±0.27[a]
0.10% (II)	13.67±1.52[a]	8.67±0.54[b]	6.00±0.47[b]	4.67±0.72[b]	3.00±0.47[b]	2.67±0.27[b]	7.33±0.27[b]
0.15% (III)	4.33±0.27[b]	6.33±0.27[c]	2.33±0.27[c]	2.33±0.27[c]	1.33±0.27[c]	2.00±0.00[b]	3.67±0.27[c]
0.20% (IV)	2.67±1.19[b]	3.33±0.72[d]	3.00±0.47[c]	0.33±0.27[d]	-	0.33±0.27[c]	1.67±0.27[d]

-*Values are Mean ± SE, values with different superscripts (a-d) in a column differ significantly at P < 0.05*

Table 55. Effect triptolide treatment on follicular kinetics (atretic follicles) in the ovaries of female *B. bengalensis*

Treatment/ group	Mean number of atretic follicles					
	Primordial	**Primary**	**Secondary**	**Tertiary**	**Pre-antral**	**Antral**
0% (I)	6.00±0.47[a]	4.33±0.27[a]	4.67±0.27 [a]	2.67±0.27[a]	2.33±0.27[a]	3.00±0.00[a]
0.10% (II)	4.00±0.47[a]	6.00±0.47[b]	3.67±0.27[a]	4.33±0.00[b]	4.33±0.27[b]	7.67±0.27[b]
0.15% (III)	5.33±0.27[a]	6.67±0.27[b]	4.67±0.27[a]	5.33±0.27[b]	4.67±0.27[b]	9.33±0.27[c]
0.20% IV)	4.33±0.27[a]	5.67±0.27[b]	4.67±0.27[a]	3.67±0.54[a]	3.67±0.27[b]	9.33±0.27[c]

-*Values are Mean ± SE, values with different superscripts (a-c) in a column differ significantly at P < 0.05*

Publications

i) Research papers

Babbar BK and Singla N. 2012. Evaluation of peppermint oil as repellent/ antifeedant against the Indian gerbil, *Tatera indica*. *Crop Improvement* (Special issue): 907-908.

Singla N and Babbar BK. 2012. Critical timings of rodenticide bait application for controlling rodents in sugarcane crop sown in Punjab, India. Sugar Tech 14(1): 76-82. (8 citations)

Singla N and Babbar BK. 2012. Critical timings and methods of rodenticide application in pea (*Pisum sativum)* crop fields. Crop Improvement (special issue): 1001-1002.

Singla N, Babbar BK and Kaur J. 2012. Farmer's participatory research on rodent control in Punjab: Survey, education, impact and sustainability. Crop Protection 34: 25-31. (3 citations)

Singla N, Kaur R, Babbar BK and Mahal AK. 2012. Repellent potential of eucalyptus and citronella oils against rodent pests infesting stored grain houses. Crop Improvement (special issue). pp. 1037-1038.

Singla N and Mittal M. 2012. Management of post control rodent population rebuildup in sugarcane. Journal of Research PAU 49(1 & 2): 60-64. (2 citations)

Dhar P and Singla N. 2013. Effect of triptolide on reproductive output of male *Bandicota bengalensis*. International Journal of Advanced Research1 (9): 705-716.

Singla N and Garg M. 2013. Effect of crude cottonseed oil containing gossypol on fertility of male and estrous cycle of female *Bandicota bengalensis* Gray and Hardwicke. Journal of Applied Animal Research 41(2): 156-165. (6 citations)

Singla N, Kaur G, Babbar BK and Sandhu BS. 2013. Potential of triptolide in reproductive management of the house rat, *rattus rattus*(Linnaeus). Integrative Zoology 8: 260-276. (11 citations)

Singla N, Kaur R and Mahal AK. 2013. Repellent effect of eucalyptus oil applied as paint against house rat, *Rattus rattus*. International Journal of Advanced Research 1: 220-229.

Singla N, Singla LD, Gupta K and Sood NK. 2013. Pathological alterations in natural cases of *Capillaria hepatica* infection alone and in concurrence with *Cysticercus fasciolaris* in *Bandicota bengalensis*. Journal of Parasitic Diseases 37(1): 16-20. (10 citations)

Babbar BK, Singla N and Singh R. 2014. Impact of village level education and training on adoption of control strategies, their sustainability and reduction in crop losses. International Journal of Advanced Research 7(2): 672-683. (1 citation)

Dhar P and Singla N. 2014. Effect of triptolide on reproduction of female lesser bandicoot rat, *Bandicota bengalensis*. Drug and Chemical Toxicology 37(4): 448-458.(3 citations)

Dhar P and Singla N. 2014. Histomorphological and biochemical changes induced by triptolide treatment in male lesser bandicoot rat, *Bandicota bengalensis*. Pesticide Biochemistry and Physiology 116: 49-55.

Dhar P, Singla N and Babbar BK. 2014. Effect of triptolide on vital organs, blood biochemical parameters and histomorphology of testis in male *Bandicota Bengalensis*. Indian Journal of Applied Research 4 (2): 27-30.

Dhar P, Singla N, Babbar BK and Shekhar C. 2014. Potential of triptolide in management of post control rodent population rebuild up in sugarcane crop fields. International Journal of Advanced Research 2 (9): 796-804.

Garg N and Singla N. 2014. Toxicity of second generation anticoagulant bromadiolone against *Rattus rattus*: individual and sex specific variations. Cibtech Journal of Zoology 3(2): 43-48.

Garg N and Singla N. 2014. Determination of lethal feeding period of bromadiolone anticoagulant for screening individual rats (*Rattus rattus*) for development of resistance. International Journal of Advanced Research 2(12): 939-945.

Singla N, Thind RK and Mahal AK. 2014. Potential of eucalyptus oil as repellent against house rat, *Rattus rattus*. The Scientific World Journal Published online, DOI: 10.1155/2014/249284.

Singla N. 2014. Antifertility effects of single oral doses of triptolide in male house rat (*Rattus rattus* L.)Applied Biological Research 16(1): 72-74.

Singla N and Challana S. 2014. Reproductive Toxicity of Triptolide in Male House Rat, *Rattus rattus*. The Scientific World Journal, Article ID 879405, 6 pages, http://dx.doi.org/10.1155/2014/879405.

Singla N and Kanwar D. 2014. Potential of poultry egg components as cereal bait additives for enhancing based control success and trap index of house rat, *Rattus rattus*. Asia Pacific Journal of Tropical Biomedicine 4(suppl 1): S314-347.

Singla N and Kaur R. 2014. Potential of citronella oil as rodent repellent measured as aversion to food. Applied Biological Research 16(2): 191-198.

Babbar BK, Kaur J, Singla N and Mahal AK. 2015. Effectiveness and persistence of cinnamic aldehyde as an antifeedant on rats under storage conditions. Crop Protection 67: 235-242.

Singla N and Babbar BK. 2015. Critical timings and methods of rodent pest management in groundnut (*Arachis hypogaea* L.) crop. Legume Research 39(1): 1-6 pages, published online. www.legumeresearch.in

Singla N, Kaur S and Javed M. 2015. Rodenticidal potential of bromadiolone and cholecalciferol in synergism against *Bandicota bengalensis*. Crop Protection 72: 163-168.

Singla N and Kaur S. 2015. Toxicity of cholecalciferolto lesser bandicoot rat, *Bandicota bengalensis*: Biochemical and histopathological changes. International Biodeterioration and Biodegradation 103: 125-133.

ii) Research notes:

Singla N. 2012. Effective doses of zinc phosphide and bromadiolone baits against female, *Rattus rattus*. Rodent Newsl36(1-4): 10-11.

Singla N. 2013. Evaluation of hing (Asafoetida) as additive for increasing bait acceptance by lesser bandicoot rat, *Bandicota bengalensis*. Rodent News l 37(1-2): 6-7.

Singla N. 2013. Critical timings of rodent control in wheat crop sown under rice residue management. Rodent News l 37(3-4): 5-6

Singla N, Kaur R and Babbar BK. 2013. Eucalyptus and citronella oils as potential repellents against house rats. Rodent News l 37(3-4): 10-11.

Singla N and Dhar P. 2014. Evaluation of triptolide as an antifertility agent against *Bandicota bengalensis*. Rodent News l 38(1-4): 6-8.

Singla N and Kaur N. 2014. Existence of short tailed mole rat, *Nesokia indica* in Kandi area of Punjab State. Rodent News l 38(1-4): 3-4.

iii) Abstracts

Singla N, Kaur R, Babbar BK and Mahal AK. 2012. Observations on behaviour of house rat, *Rattus rattus* in response to eucalyptus and citronella oils as repellents in maze experiments. Proceedings of Second International Conference on Allelopathy: A Multi-faceted Process under the Aegis of Asian Allelopathy Society held at Panjab University, Chandigarh, India from December 14-18, 2012, Pg 104-105.

Singla N and Babbar BK. 2012. Evaluation of an herbal chemosterilant for management of *Rattus rattus* population in poultry farms. Proceedings of International Symposium on One Health: Way Forward to Challenges in Food Safety and Zoonoses 21st century and XIth Annual Conference of Indian Association of Veterinary Public Health Specialists held at GADVASU, Ludhiana from 13-14 Dec, 2012, Abstract ID: OHS-149-ABS.

Babbar BK and Singla N. 2012. Rodent pest management in wheat and rice grain stores. Proceedings of International Symposium on One Health: Way Forward to Challenges in Food Safety and Zoonoses 21st century and XIth Annual Conference of Indian Association of Veterinary Public Health Specialists held at Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India GADVASU, Ludhiana, Punjab, India from December 13-14, 2012, Abstract ID: OHS-268-ABS.

Singla N and Swati. 2012. Efficacy of triptolide in population regulation of *Rattus rattus* (Linnaeus) in poultry farms. Proceedings of 15th Punjab Science Congress held at Guru Nanak Dev University, Amritsar, Punjab, India from February 7-9, 2012, Pg 8.

Singla N,Singla LD, Gupta K and Sood NK. 2012. Pathological alterations in natural cases of *Capillaria hepatica* infection alone and in concurrence with *Cysticercus fasciolarisin Bandicota bengalensis*. Proceedings of XXII National Congress of Indian Association for the Advancement of Veterinary Parasitology (IAAVP) and National Symposium on Integrated Research Approaches in Veterinary Parasitology: From Basic to Molecular Techniques held at College of Veterinary Science and Animal Husbandry, Mathura, Uttar Pradesh, India from March 15-17, 2012, Pg 112.

Singla N, Dhar P and Gupta K. 2013. Potential of nifedipine as antifertility agent against male lesser bandicoot rat, *Bandicota bengalensis*. Proceeding of 5th International Symposium of Integrative Zoology held at Beijing, China from June 25-28, 2013, Pg 35-36.

Singla N, Kaur R and Mahal AK. 2013. Repellent potential of eucalyptus oil applied as paint against house rat, *Rattus rattus*. Proceedings of 6th International Conference on Recent Advances in Chemical and Environmental Sciences (Including Biological Sciences) held at Multani Mal Modi College, Patiala, Punjab, India from November 13-14, 2013, Pg 93.

Dhar P and Singla N. 2013. Effect of triptolide on reproduction of female lesser bandicoot rat, *Bandicota bengalensis*. Proceedings of 6th International Conference on Recent Advances in Chemical and Environmental Sciences (Including Biological Sciences) held at Multani Mal Modi College, Patiala, Punjab, India from November 13-14, 2013, Pg 96.

Dhar P and Singla N. 2014. Effect of triptolide on reproduction of male lesser bandicoot rat, *Bandicota bengalensis*. Proceedings of International Conference on Crop Productivity & Sustainability – Shaping The Future held at Baba Farid College, Bhatinda, Punjab, India from March 20-21, 2014, Pg 365-366. (Received First Best Poster Award)

Singla N, Kaur R and Mahal AK. 2014. Repellent effect of eucalyptus oil encapsulated in wax blocks against house rat, *Rattus rattus Linnaeus*. Proceedings of International Conference on Crop Productivity & Sustainability – Shaping The Future held at Baba Farid College, Bhatinda, Punjab, India from March 20-21, 2014, Pg 369.

Singla N. 2014.Role of rodents as reservoirs and insects as vectors in transmission of rodent borne diseases. Proceedings of International Conference on Entomology held at Punjabi University Patiala from February 21-23, 2014, Pg 59. (Invited paper)

Garg N and Singla N. 2014. Standardization of blood clotting response test for detecting resistance to second generation anticoagulant rodenticide in house rat, *Rattus rattus*. Proceedings of 2nd Annual National Conference on Science: Emerging Scenario and Future Challenges-II held at Himalayan Forest Research Institute, Conifer Campus, Panthaghati, Shimla, Himachal Pradesh, India from May 17-18, 2014, Pg 112.

Singla N and Kaur R. 2014. Potential of citronella oil as repellent in reducing food consumption by house rat, *Rattus rattus*. Proceedings of 2nd Annual National Conference on Science: Emerging Scenario and Future Challenges-II held at Himalayan Forest Research Institute, Conifer Campus, Panthaghati, Shimla, Himachal Pradesh, India from May 17-18, 2014, Pg 113.

Babbar BK, Kaur J, Singla N and Mahal AK. 2014. Development of effective cinnamamide formulation with antifeedant effect to prevent rodent damage in grain stores. Proceedings of National Conference (Science Colloquium) on Emerging Trends in Basic and Applied Sciences held at DAV College, Jalandhar, Punjab, India from March 06-07, 2014, Pg 94.

Kaur R and Singla N. 2014. Repellent effect of citronella oil applied as spray and as encapsulated wax blocks against house rat, *Rattus rattus Linnaeus*. Proceedings of 5th International Conference on Rodent Biology and Management held at Zhengzhou, Henam, China from August 25-29, 2014, Pg 220. (Young Scientists Award)

Garg N and Singla N. 2014. Investigation of the current status of bromadiolone resistance in *Rattus rattus* population in Punjab, India. Proceedings of 5th International Conference on Rodent Biology and Management held at Zhengzhou, Henam, China from August 25-29, 2014, Pg 221. (Young Scientists Award)

Garg N and Singla N. 2015. Determining of lethal feeding period of bromadiolone bait for screening rats (*Rattus rattus*) for development of resistance. Proceedings of 7th International Conference

on Recent Advances in Chemical, Biological and Environmental Sciences held at Multani Mal Modi College, Patiala, Punjab, India from January 30-31, 2015, Pg 11.

Kaur R, Singla N, Bansal N and Pathak D. 2015. Histochemical changes induced by red chilli powder in stomach and small intestine of female house rat (*Rattus rattus*). Proceedings of XXIX Annual Convention of Indian Association of Veterinary Anatomists and National Symposium on Recent Concepts and Applications of Veterinary Anatomy for Improvement of Livestock Health and Production held at Chhatisgarh Kamdhenu Vishwavidyalaya, Durg, Chattisgarh, India from February 11-13, 2015, Pg 20.

Kaur N, Singh R and Singla N.2015. A study on comparison of paper bait and tyre bait stations for control of rodents in rice crop. Proceedings of 18th Punjab Science Congress held at Desh Bhagat University, Mandi Gobindgarh, Punjab, India from February 7-9, 2015, Pg 105-06.

Singh R, Kaur N and Singla N. 2015. Determination of critical timings and methods of rodent control in direct seeded and transplanted basmati rice crops. Proceedings of 18th Punjab Science Congress held at Desh Bhagat University, Mandi Gobindgarh, Punjab, India from February 7-9, 2015, Pg 143.

iv). Review articles/chapters/occasional paper

Singla N. 2013. Rat control in poultry farms. In: Compendium released during 'Special Training Course for Poultry Inspectors' Singh P, Verma HK, Kansal SK and Singh J (eds), pp 76-79. Department of Veterinary and Animal Husbandry Extension Education, GADVASU, Ludhiana (In Punjabi).

Singla N. 2014. Rats In: Problems in Cultivation of Vegetable Crops, Sharma A (ed), pp 232-238. Centre of Communication & International Linkages, PAU, Ludhiana. (In Punjabi).

Singla N, Kocher DK, Kaur R, Parshad VR and Babbar BK. 2013. Recent Advances in Rodent Research in Punjab. Indian Council of Agricultural Research, New Delhi. pp 1-56.

v) Popular articles

a) In English:

Singla N andBabbar BK. 2012. Rodent control in wheat. Progressive Farming. 48 (3): 24-25.

Kaur N and Singla N. 2014. Rodent control in zero tillage wheat crop fields. Indian Farming 64(8): 39-40.

Singla N and Singh R. 2015. Reduce rodent losses to food grains in store houses. Progressive Farming 51(5): 16-17, 19.

b) In Punjabi:

Singla N. 2012. Murgi khaniyan vich chuyian de roktham. Vigyanak Pashu Palan 5(6): 25-27.

Singla N. 2012. Mukh phaslan nu chuhiyan de nuksan ton kivaen bachaey? Rojana Ajit, Part I on 06.09.12 and Part II on 13.09.12. Kheti Duniya dated 22.09.12 (Special Kisan Mela Issue), pp 18 and Kheti Duniya dated 24.11.12, pp 9.

Singla N, Babbar BK and Singh R. 2013. Chonae de phasal nu chuhiyan de nuksan ton bachao. Kheti Duniya (special Kharif issue) 31(27): 2, 6.

Singh R,Singla, N and Babbar BK. 2013. Gane de phasal vich chuhiyan ton nuksan ate roktham. KhetiDuniya 31(28): 5.

Singla N. 2014. Kanak de phasal nu ajehvi chuhiyan de nuksan ton bachayeajasakdahai. Kheti Duniya (KisanMela Special Issue) 32(11): 10.

Kaur N and Singla N. 2014. Bina bahaibijikanak de phasalvichchuyian de roktham. KhetiDuniyan dated 25.10.14, pp 10-11.

Singh R,Singla, N and Babbar BK. 2014. Mungphalli de khetanvichchuhiyan da nuksan ate roktham. KhetiDuniyan 32(25): 16.

Singla N and Singh R. 2015. Ann Bhandar nu chuyian ton bachao. ChengiKheti51(5): 22-23.

News item in Newspapers:

Singla N. 2012. Rats, the biggest foe of food grains. Punjab Kaseri Ludhiana edition dated 20.07.12 (In Hindi); Jag Bani Ludhiana Edition dated 23.07.12. (In Punjabi); Kheti Duniya dated 04.08.12, pp 9. (In Punjabi).

Singla N. 2014. Rats cause damage worth crores every year. Punjab Kaseri Ludhiana edition dated 23.05.14, pp 3. (In Hindi); Jag Bani Ludhiana edition dated 23.05.14, pp 4. (In Punjabi)

Singla N. 2015. Rat population is increasing at a faster rate: Bandicoot, the most dangerous rat. Punjab Kesari Ludhiana edition dated 27.04.15. (In Hindi).

Punjab Agricultural University, Ludhiana

Actual expenditure for the FY 2012-13 to 2014-15

(ICAR Share only)

(Rs. in lakhs)

Head/ Year	2012-13	2013-14	2014-15	Total
Pay & Allowances	51.48	42.82	45.57	**139.87**
T.A.	0.53	1.06	0.75	**2.34**
Rec. Contingencies	1.79	3.00	5.50	**10.29**
NRC	0.00	0.00	0.00	**0.00**
Total	**53.80**	**46.88**	**51.82**	**152.50**

UNIVERSITY OF AGRICULTURAL SCIENCES, GKVK, BENGALURU

PART I: GENERAL INFORMATION

1. Name of the centre	University of Agricultural Sciences, GKVK, Bengaluru
2. Sanction no.	5/4-78PP dated 23.05.1980
3. Date of start	January 1978 under DST (No HCS/DST/255/76) and from May,1980 under ICAR
4. Date of Termination	Network Project of continued nature
5. Report period	2012-13 to 2014-15
6. Scientist In charge	Dr. G. Govind Raj

7. Staff Position

Sr. No.	Name of post	No. of posts sanctioned	Name of incumbent with present post & pay scale	Date of Joining	Date of Leaving
I.	Sr. Zoologist & Scheme Head	1	1. Dr. G. Govind Raj Professor & Scheme Head(wef 17.10.2014) Rs.37400-67000+ 10000 AGP	13.08.2003	Contd
			Dr V. Shivayya Professor & Scheme Head (30.04.2007 to 16.10.2014) Rs.37400-67000+10000 AGP	01.12.2005	31.05.2015
2	Zoologist	1	Dr Mohan I. Naik Professor Rs.37400-67000+10000 AGP	29.07.2009	Contd
3	Technical Assistants	2	Mr Sidappa Kannur 9300-34800+4200 AGP	15.11.2010	01.08.2013
4	Jr. Stenographer	1	Mrs M. Lalitha (Rs 14550 fixed on contract)	12.12.2009	Contd
5	Field Assistants	2	Mr Y. Muniraju (Rs16000-29600)	24.08.2005	31.12.2014
			Mr B. Basavraju (Rs 16000-29600)	14.09.2009	Contd
			Mr S.N. Ramakrishna (Rs 16000-29600)	08.10.2011	Contd
6	Lab Attender	2	MrRajanna Rs11600-21000	24.07.1987	30.06.2014
			Mr J.D. Narayan Shetty Rs11600-21000	10.04.2008	Contd
			Mr Channakeshava (Messenger: Rs9600 fixed)On temp. basis	04.02.2015	Cond

PART II: WORK ALLOTTED

R.M. 1 Surveillance of rodents in predominant cropping systems.
R.M. 2 Monitoring of rodent abundance and damage in selected agro-climatic zones of Karnataka
R.M. 3 Evaluation of botanical against rodent pest for antifeedant/deterrent/attractant effects
R.M. 4 Evaluation of chemical compounds for toxic and anti-fertility properties for data generation on Indian rodents.
R.M. 5 Development of rodent management technologies under storage conditions
R.M. 6 Bio ecology of *Bandicota indica* (Habit, habitat, food, feeding,/burrowing behavior, population dynamics, reproduction & breeding biology etc.,)
R.M. 7 Development refinement of rodent pest management modules in predominant crops/ cropping systems
R.M. 8 Social Engineering Activity on Rodent Pest Management, as Participatory Adaptive Research in Adopted villages

LOCATION SPECIFIC PROGRAMMES

- Rodent problem in Poly house agriculture and development of management strategies
- Rodent management in grape gardens under drip irrigation.
- Operational trials on trunk banding technology for rodent management in coconut.
- Evaluation of traps for capturing varied sized rodents
- Lab evaluation of Difenacoum and flocoumafen against *Mus musculus* and their field evaluations in rice and coconut and under commensal situations (stores/godowns etc) as sponsored trial from BASF India PVT. Ltd.

PART III: WORK DONE

1. SURVEILLANCE OF RODENTS IN PREDOMINANT CROPPING SYSTEMS

Studies were undertaken during 2012-15 on the species composition of rodent pests in selected agroclimatic zones of Karnataka. The agroclimatic zones and the cropping systems studied were (i) Northern Transition Zone (NTZ): Soybean- Bengal gram at Bidar (ii)North Eastern Dry Zone (NEDZ): Red gram (kharif)- Fallow at Gulbarga and (iii) Hilly zone: Paddy-Cowpea in North Canara. The population of rodents were monitored by live burrow count (LBC/ha) and trapping methods. The incidence of rodent's damage was also studied and recorded in relation to the growth stage of the crops. Salient findings are:

1.1. Soybean-Bengalgram cropping system in Northern Transition Zone at Bidar The rodent pest species were *Bandicota bengalensis, Tatera indica and Millardia meltada.* Throughout the study period, maximum rodent population in soybean was seen during pod formation in August/September (47-50 LBC/ha) and maximum rodent damage of 2.13 to 4.86% was seen during harvest stage in September/October. The per cent pregnancy varied from 44 to66%, maximum being during pod formation in September/October months. The results for the year 2012-15 are presented in Table 1.

Table 1. Surveillance of rodent population in Soybean and Bengal gramcropping system (2012-13 to 2014-15)

Crop stage	Month	Rodent density (LBC/ha)				Mean	Rodent Damage (%)			Mean	Mean pregnancy (%)	Yield loss (Kg/ha)
		12-13	13-14	14-15			12-13	13-14	14-15			
Soybean												
Sowing	June	13	17	14		14.66	-	2.7	0.0	1.35	-	65.00
Veg. stage	July	27	22	27		25.33	2.0	2.1	2.3	2.13	44.44	
Pod formation	Aug.	34	51	58		47.66	3.7	5.6	5.3	4.86	66.66	
Harvest	Sept.	51	55	45		50.33	4.8	5.8	2.3	4.30	58.33	
Bengalgram												
Sowing	Oct.	41	42	46		43	5.1	4.6	4.2	4.63	61.12	58.00
Pod formation	Nov.	45	62	58		55	2.7	5.45	5.40	4.50	69.44	
Harvest	Dec.	58	65	69		64	6.3	6.1	6.6	6.33	30.55	

Species Composition: *Bb-Bandicota bengalensis>Ti- Tetera indica>Millardia meltada*

1.2. Redgram (kharif)-fallow in North Eastern Dry Zone at Gulbarga

The maximum population 50 to 67 LBC/ha was seen during harvest in October - November and 5.27% cropdamage was been during harvest in October / November. Per cent pregnancy 87% being maximum during grain formation stage. The rodent pests were *B. bengalensis, M. meltada, T. indica and Mus platythrix.*The results for the year 2012-15 are detailed in Table 2.

Table 2. Surveillance of rodent population in Red gram (mono cropping) cropping system (2012-13 to 2014-15)

Crop stage	Month	Rodent density (LBC/ha)			Mean	Damage (%)			Mean	Mean pregnancy (%)	Yield loss (Kg/ha)
		12-13	13-14	14-15		12-13	13-14	14-15			
Fallow land	Apr-June	-	-	-	-	-	-	-	-	-	47.50
Sowing	July	-	27	33	30.0	-	2.8	3.1	2.95	41.66	
Veg/ Tillering	Aug/Sept	-	59	42	50.5	-	5.7	2.6	4.15	87.50	
Harvest	Oct/Nov	-	67	68	67.50	-	3.8	6.75	5.27	75.00	

Species Composition: *Bb-Bandicota bengalensis>Mme- Millardia meltada>Mp- Mus platythrix>Ti-Tetera indica*

1.3. Paddy- cowpea in Hilly zone at Sirsi

Maximum rodent population of 69 to 80 LBC/ha was seen during harvest stage of the paddy coincides with maximum rodent damage 7.57% and peak per cent pregnancy (55.63%), was seen during ear head formation in September. The expected yield loss was about 24 kg/ha. The rodent species were *M. booduga, B. bengalensis, M. meltada.* In cowpea, it was during harvest stage, maximum population (70 LBC/ha) was seen coincides with maximum crop

damage of 6.35%. The pregnancy of predominant rodents varied from 36 to 66% during the period. The data for the year 2012-15 is presented in Table 3.

Table 3. Surveillance of rodent population in Paddy-Cowpea cropping system

Crop stage	Month	Rodent density (LBC/ha)			Mean	Rodent Damage (%)			Mean	Mean pregnancy (%)	Yield loss (Kg/ha)
		12-13	13-14	14-15		12-13	13-14	14-15			
Rice											24.00
Sowing	June/July	37	32	35	34.66	4.78	2.7	2.3	3.26	63.00	
Tillering	Aug./Sept.	58	43	-	50.5	2.6	3.5	-	3.05	55.00	
E.H. form	Sept./Nov.	76	62	69	69.0	3.75	4.6	5.7	4.68	47.25	
Harvest	Nov./Dec.	82	77	82	80.33	7.23	7.3	8.2	7.57	47.25	
Post harvest	Dec.	56	83	-	69.50	-	-	-	-		
Species Composition: *Mus booduga>Bandicota bengalensis>Millardia meltada*											
Cowpea											
Sowing	Feb.	39	37	32	36.0	3.08	2.6	2.8	2.83	36.00	85.00
Veg. Phase	March	40	42	-	41.0	4.35	4.4	-	4.37	50.00	
Harvest	April/May	-	57	84	70.50	-	5.8	6.9	6.35	66.66	
Species Composition: *Bandicota bengalensis>Mus booduga*											

2. MONITORING OF RODENT ABUNDANCE AND DAMAGE IN SELECTED AGRO CLIMATIC ZONES OF KARNATAKA

This project was undertaken in three agro-climatic zones of Karnataka. They were North Eastern Dry Zone at Gulbarga (Soybean and Bengal gram crops): Southern Dry Zone at Chamrajanagara (Ground nut and ragi) and Hilly Zone at Sirsi, Kumta and North canara (Coconut, pine apple). Salient findings of the three year study are briefed as under;

2.1. In sorghum in Northern Eastern dry zone at Gulbarga

Maximum rodent population 46 to 58 LBC/ha was seen during grain formation in Sept/Oct, with maximum incidence 3.8 to 5.8% The rodent specie were T. indica, B. bengalensis. M meltada (Table 4)

Table 4. Monitoring of rodent abundance and their damage in various crops

Crop	Maximum population LBC/ha			range	Maximum incidence (%)			Range	Species composition
	2012-13	2013-14	2014-15		2012-13	2013-14	2014-15		
Bengal gram	49-65 (Pod form/ Harvest)	57-65 (Pod form/ Harvest)	45-63 (Pod form/ Harvest)	45-65	2.7-6.8 (Pod form/ Harvest)	5.7-6.6 (Pod form/ Harvest)	3.6-6.7 (Sowing/ Pod form)	2.7-6.8	*Bb>Ti>Mme*
Sorghum	46-58 (Grain form./	50-54 (Grain form /harvest)	50-56	46-58	3.8-5.8 (Grain form	3.9-5.7	2.7-4.36	2.7-5.7	*Ti>Bb>Mme*

	harvest)		(Grain form /harvest)		/harvest)	(Grain form /harvest)	(Sowing/ Harvest)		
Ragi	56-63 (pod form/ Harvest)	46-53 (grain filling/Harvest)	58-63 (Milkygrain / harvest)	46-63	5.32-7.2 (harvest / grain filly)	3.9-6.13 (grain filly /harvest)	4.4-5.3 (grain form. / harvest)	4.4-7.2	*Bb>Ti>Mb*
Ground nut	57-62 (Pod form/ post harvest)	45-72 (Pod form./ harvest)	68-75 (Pod form / post harvest/ sowing)	45-75	5.8-6.4 (Harvest / sowing)	3.9-6.1 (pod form./ harvesting)	4.56-6.7 (sowing / pod. form)	3.9-6.7	*Bb>Ti>Mb*
Pineapple	26-41 (fruit form)	43-67 (fruit form)	51-76 (fruit form)	26-74	2.3-4.7 (fruit form)	2.8-5.8 (fruit form)	2.6-5.0 (fruit form)	2.3-5.8	*Mb>Bb>Ti*

Incidence (%)					Mean	RI			Mean	species
Coconut		2012-13	2013-14	2014-15		2012-13	2013-14	2014-15		
	Range (mean)	1.6-12.6 (5.31)	3.4-11.4 (7.05)	2.53-12.68 (6.42)	1.60 - 12.63 (6.26)	-	6.5-24.5 (15.52)	6.2-26.5 (14.70)	6.2-26.5 (15.11)	Fp>Rr>Bb
	Max. Incidence	Mar-May	Mary-May	Dec-Apr		-	Dec-May	Dec-Apr		

2.2. In Bengal gram in North Eastern dry zone at Gulbarga

Maximum population of 57 to 65 LBC/ha was seen during pod formation / harvest stage of the crop in December/January also coincides with peak crop damage 2.7 to 6.8% due to *B. bengalensis, T. indica and M. meltada.*

2.3. In ground nut in Southern dry zone at Chamarajanagara

Maximum rodent population recorded was 68 to 75LBC/ha during pod formation /harvest in October / November, also coincides with peak crop damage 4.56 to 6.70 due to *B. bengalensis, T. indica and M.booduga.*

2.4. In Ragi in Southern Dry Zone at Chamarajanagara

Also maximum population was been during grain filling stage 58 to 63 LBC/ha coincides with peak crop damage 5.32 to 7.2% due to similar rodent pest species composition.

2.5. In pineapple in hilly zone at Sirsi

Peak population was recorded during fruit formation 51 to76 LBC/ha, coincides with peak fruit damage 2.3 to 5.8%. The rodent species were *M. boodugaB. bengalensis and T. indica.*

2.6. In coconut (20 years old) in Hilly zone at Kumta

Maximum rodent population 2.53 to 12.68 LBC/ha, 6.2 to 26.5% incidence was been during December/April; coincides with peak nut damage. The predominant rodent pests were *F. palmarum, R. rattus and B. bengalensis.*

3. EVALUATION OF CHEMICAL COMPOUNDS FOR TOXIC AND ANTIFERTLITY PROPERTIES ON INDIAN RODENTS

The studies on laboratory and field evaluation of two new anticoagulant rodenticides viz, Difencoum (0.005%) and Flocoumafen (0.0055) was carried out during the period under report. The study was part of multi-location testing of rodenticides sponsored by M/S BASF, India Pvt. Ltd.

3.1. LABORATORY TRIALS

(a) DIFENACOUM

The experiments were conducted against *Musmusculus* collected fresh from the various godowns/stores and were weighed, sexed, lodged individually in laboratory cages for acclimatization for 10-15days. Normal food and water was provided during this period. After acclimatization, healthy animals of almost uniform body weight were selected. Before initiating the trials, the body weight of each animal was recorded and subsequently data on consumption of food daily for three days (pre-treatment daily consumption) was recorded animal wise. After third day, under no choice a known quantity (10g each) of Difenacoum(0.005%) poison bait was exposed to the test animals for two days continuously and no other food was provided during the experiment. Water was provided *ad libidum* and the consumption by each individual was recorded. After two days of bait exposure, the poison bait was withdrawn and the normal food was provided to the test rodents till their death and the data of daily intake was recorded to work out mortality (%) and days death (mean and range). For choice tests, the experimental mice were provided with both plain food as well as poison bait to record the palatability and acceptability of poison bait *vis a vis* a plain bait and mortality and days to death.

Results:

No-choice Tests: In the no-choice tests, the per cent mortality of house mouse was 90 per cent when difenacoum was offered for two days continuously and the time taken for mortality was 5.64$\pm$ 0.80 days with a range of 5-7 days (Table 5). The average weight of house mouse was 14.71$\pm$ 1.69 g (12.50 to 17.50 g). The food consumption prior to treatment by individual animal was 16.04 $\pm$ 1.35 g/100 g body weight (14.12 to 18.64 g). During the treatment the total baits consumption for two days 27.36 $\pm$ 5.36 g (5.86 to 33.96 g) per 100 g body weight. The total difenacoum(0.005%) toxicant taken inside the body by individual animal was 136.80$\pm$ 26.83 mg per kg body weight with a range of 79.30 to 169.80 mg.

Choice Tests: The results of choice tests exhibited a mean mortality of 75.00 per cent when the plain food and rodenticide baits were offered simultaneously for two consecutive days. The average days of mortality was 6.66 with on a range of 5-8. During treatment the consumption was 10.54$\pm$5.40 g and 20.02$\pm$1.52 g/100 g body weight for plain and poison respectively. The

average toxicant consumption by individual animal was 100.10±37.50 mg/kg body weight, with a range of 29.40-159.60 mg/kg body weight (Table 5).

Table 5. Consumption of difenacoum (0.005%) ready to use (Wax block) baits and mortality patterns in *Mus musculus* under no-choice test & choice test

Feeding Period (Days)	Mean body wt Mean ± SE	Pre-treatment consumption (g/100g body wt) Mean ± SE	Poison consumption (g/100g body wt) Mean ± SE	Anticoagulant consumed (mg/kg) Mean ± SE	Mortality	Days to death Mean± SE (range)
no-choice test						
2	14.71± 1.69 (12.5 -17.5)	16.04± 1.35 (14.19-18.64)	27.36± 5.36 (15.86-33.96)	136.80 ± 26.83 (79.30 -169.8)	9/10	5.64± 0.80 (5-7)

Choice Test

Feeding period (Days)	Body wt. Mean ± SE	Pretreatment Food consumption (g/100 gbody wt.) Mean ± SE	Mean daily bait intake Mean ± SE			Paired student 't' test between Poison and plain bait significance	Mortality	Days to death
			Poison		Plain			
			g/100g body weight Mean ± SE	Poison consumed (mg/kg) Mean ± SE	g/100g body weight Mean ± SE			Mean± SE (range)
2	14.6 ± 1.2 (13 – 17)	15.60 ±0.90 (14.38-17.42)	20.02±7.52 (5.88-31.92)	100.10±37.50 (29.40 - 159.6)	10.54±5.40 (5.17-21.76)	Sig.	9/12	6.66±3.13 (5-8)

(b) FLOCOUMAFEN

The experiments were conduct against *Mus musculus* following similar methods as explained with difenacoum. The results are as follows;

No-choice Tests: In the no-choice tests, the per cent mortality of house mouse was 91.66 per cent when flocoumafen was administered for two days continuously and the time taken for mortality was 5.30 days with a range of 4-7 days (Table 6). The food consumption prior to treatment by individual animal was 16.48 g/100 g body weight. During the treatment the total bait consumption was 3.97 g (13.26±1.60 g per 100 g body weight). The mean a.i. of flocoumafen toxicant was 102.50 mg per kg body weight.

Choice Tests: The results of choice tests exhibited a mean mortality of 75.00 per cent when the plain food and rodenticide baits were provided simultaneously. The mean days for mortality was6.37with on a range of 6-8 (Table 6). During treatment the mean poison and plain food consumption by individual was 1.10 g and 1.31g, respectively, while the total food and bait intake in g/100 g body weight was 8.83 and 7.72 g, respectively during treatment. The average toxicant consumption was 54.37±10.30 mg/kg body weight, with a range of 27.50-100.0 mg/kg body weight (Table 6).

Table 6. Consumption of flocoumafen (0.005%) ready to use (wax block) baits and mortality patterns in *Mus musculus* under no-choice and choice tests.

Feeding Period (Days)	body wt Mean ± SE	Pre-treatment consumption (g/100g body wt) Mean ± SE	Mean daily bait intake Mean ± SE			Paired student 't' test plain and poison consumption	Mortality	Days to death	
			Poison		Plain				
			g/100g body wt	Poison consumed (mg/kg)	g/100g body wt			Mean ± SE	Range
No-choice test									
02	15.45 + 0.39 (13-18)	16.48 ± 1.72 (13.74-19.70)	13.26 ± 1.60	102.50 ± 12.48	-	-	11/12 (91.66%)	5.3 ± 0.64	(4-7)
Choice test									
02	14.00 ±0.40 (12-16.50)	15.60 ± 0.90 (14.38-17.42)	7.72±1.37	54.37± 10.30	8.83 ± 10.30 (3.22-16.66)	NS	9/12 (75%)	6.37± 0.50	(6-8)

3.2. FIELD TRIALS WITH DIFENCOUM

(i) Rice: Studies on the bioefficacy of difenacoum(0.005%) wax blocks were conducted in summer paddy and second season at ZARS, Mandya, Karnataka.

During the first season trial the pre control census indicated that the live burrow count ranged from 33 to 39/ha with an average of 35.33/ha and the damage incidence ranging from 3.2 to 3.6 per cent with an average of 3.40 per cent. After 15 days of imposing of treatment, the results revealed that difenacoum reduced the live burrow counts ranging from 15 to 16/ha with an average of 15.66 LBC/ha and the tiller damage ranged from 1.39 to 1.63 with an average of 1.47 (Table 7). The rodent control success with 1stpulse of rodenticide registered a mean reduction of 55.45 LBC and 56.70% of incidence over pre control census. Rodent incidence after the application of second pulse (15 days after first one), revealed that the live burrows ranged from 7-8/ha with an average of 7.33 and tiller damage varied from 0.63 to 0.80 per cent with an average of 0.69 per cent. Thus final control success recorded a reduction 79.07% LBC and 79.64% of tiller damage over pre control census (Table 7).

Table 7.Bioefficacy of difenacoum (0.005%) wax blocks against rodent pests inSummer Rice, 2013 (Season-I)

		Difenacoum				Control			
		R1	R2	R3	Mean	R1	R2	R3	Mean
Pre Control Census	No of burrows	39.00	34.00	33.00	35.33	35.00	38.00	34.00	35.66
	Damage incidence (%)	3.40	3.60	3.20	3.40	3.20	3.60	3.70	3.50
Mid Control Census	No of burrows	16.00	15.00	16.00	15.66	39.00	41.00	42.00	40.66
	Damage incidence (%)	1.40	1.63	1.39	1.47	3.60	3.70	4.00	3.77
Final Control Census	No of burrows	7.00	7.00	8.00	7.33	62.00	59.00	67.00	62.66
	Damage incidence (%)	0.63	0.80	0.65	0.69	5.30	5.20	5.50	5.33
Control Success with first pulse (%)	No of burrows	58.97	55.88	51.51	55.45	111.12	107.89	113.51	110.94
	Damage incidence	58.82	54.72	56.56	56.70	112.50	102.78	108.11	107.79
Final control success (%)	No of burrows	82.05	79.41	75.75	79.07	177.14	155.26	197.05	176.49
	Damage incidence	81.47	77.77	79.68	79.64	165.62	144.44	148.64	152.90

The second season trials were conducted in the farm area of Regional Agricultural Research Station, Mandya during Rabi 2013-14. The result indicated that the pre control census of LBC was 102.00/ha, whereas in case of 7 days after 1stpulse application, the mean LBC was 30 per hectare. After 2nd application the LBC was reduced to 8.66/ha. (Table. 8). Overall control success after two pulses on the basis of burrow count was 71.13% with difenacoum(0.005%) wax blocks and 67.37 with bromadiolone(0.005%). After first pulsing and second pulsing with difenacoum(0.005%) wax blocks, the per cent of damage registered as 2.36 and 0.75 per cent, respectively. The overall control success in burrow count and tiller damage incidence was 71.13 and 90.87, respectively (Table 8& 9). Almost similar control success was observed with bromodiolone also.

Table 8.Bioefficacy of difenacoum (0.005%) wax blocks against rodent pests in Summer Rice, 2013 (Season-I) - Burrow Count Method.

	Parameters	No. of Rodents burrows/ha			Average	% reduction
		R1	R2	R3		
Pre-treatment	Difenacoum	107	98	101	102.00	
	Bromodiolone	105	102	89	98.66	
	Untreated check	102	98	105	101.66	
7 days after first treatment	Difenacoum	33	29	28	30.00	70.58
	Bromodiolone	34	32	29	31.66	67.90
	Untreated check	105	101	106	104.00	-
7 days after second treatment	Difenacoum	9	9	8	8.66	71.13
	Bromodiolone	9	10	12	10.33	67.37
	Untreated check	108	106	107	107.00	-

Table 9. Bioefficacy of difenacoum (0.005%) wax blocks against rice field rodents during kharif, 2013 (Season-II) - Damage incidence Method.

Sl. No.	Parameters	% Damage			% Reduction over		% Reduction over control	
		Pre treatment	14 Days after first treatment	14 Days after second treatment	14 Days after first treatment	14 Days after second treatment	14 Days after first treatment	14 Days after second treatment
1	Difenacoum	7.30	2.36	0.75	67.67	68.22	69.85	90.87
2	Bromodiolone	7.25	2.60	1.04	64.13	60.00	66.79	87.34
3	Control	7.23	7.83	8.22				

(ii) Storage: The difenacoum(0.005%) wax block was evaluated for its efficacy against rodents in stores of GKVK campus, University of Agricultural Sciences, Bangalore. The efficacy was evaluated by using two census methods *viz.*, (i) Trapping index and (ii) tracking.

The results on the evaluation by trapping index method (Table 10) indicated that the trapping index during pre-control census was 29.45 in treatment store and 31.67 in control store. However, after 15 days of treatment the control success was 69.59 per cent with trapping index of 8.89 while in control there was no change (31.67). The second pulse of treatment yielded control success of 86.78 per cent with a trapping index of 3.89. In control store there was an increase in the population by 5.50 and 16.66 per cent after 15 and 30 days, respectively. The efficacy of new rodenticide against rodents after second pulse of treatment as assessed by tracking the activity method (Table 11) was 84.74 per cent with the tracking activity index of 29.67. After Ist dose, the reduction in rodent population was 61.11 per cent only.

Table 10.Bioefficacy of difenacoum(0.005%) wax blocks against commensal rodents in Storage (Season-I)–Trapping method.

	Control	**Difenacoum**			**Mean**	**Control**
		Trapping index				
		R1	**R2**	**R3**		
Pre control Census	31.67 (19.00)	25.00 (15)	31.67 (19)	31.67 (19)	29.45 (17.67)	30.00 (18.0)
Mid control Census	31.67 (19.00)	8.33 (5)	10.00 (6)	8.33 (5)	8.89 (5.33)	31.67 (19.00)
Mid controlsuccess (%)	0.00	66.66	68.42	73.68	69.59	5.50
Final control Census	33.33 (20.00)	3.33 (2)	5.00 (3)	3.33 (2)	3.89 (2.33)	35.00 (21.00)
Final control uccess (%)	10.53	86.67	84.21	89.47	86.78	16.66

Figures in parenthesis indicates the actual trapping from 20 traps in three nights.

1. Mid census was done 15 days after first pulsing /application and 2. Final census was done 15 days after second pulsing/application.

Table 11.Bioefficacy of difenacoum(0.005%) wax blocks against commensal rodents in Storage (Season-I)–Tracking method.

	Difenacoum			Mean	Control
	Tracking activity				
	R1	R2	R3		
Pre treatment	211.11(19)	200.00(18)	166.66(15)	192.59 (17.3)	199.99(18)
10 days after Ist dose	133.33(12)	122.2 (11)	111.11(10)	122.22 (11.0)	211.11(19)
Control Success after Ist dose (%)	63.15	61.11	66.67	61.11	5.55
10 days after IInd dose	33.33(3)	33.33(3)	22.22(2)	29.67(2.67)	222.2(20)
Control Success after IInddose (%)	84.21	83.33	86.67	84.74	11.11

Another trial was conducted at UAS, GKVK, NSP store, Bangalore. The pre control infestation levels revealed that the average bait consumption, number of burrows and trapping index were 6.33, 8.33 and 7.66, respectively. In mid control census the results indicated that the average trapping index 1.66, (Table 12). The final control success as assessed by trap index was, mean 80.46.

Table 12. Bioefficacy of difenacoum(0.005%) wax blocks against commensal rodents in Storage (Season-II) Trapping method.

	Difenacoum			**Mean**	**Control (Mean)**
	Trapping index				
	R1	***R2***	***R3***		
Pre control Census	7.66	8.33	6.33	7.44	11.10
Mid control Census	1.66	1.00	1.66	1.66	1.44
Mid controlsuccess (%)	69.58	80.07	84.2	77.95	9.55
Final control Census	1.66	1.33	1.33	1.44	9.55
Final control success (%)	78.38	84.03	78.98	80.46	-

(iii) Coconut: The bioefficacy of Difenacoum(0.005%) wax blocks was evaluated during 2013 and 2014 in coconut for two seasons.

First Season trail: This experiment was under taken at ZARS Mandya in about 20 years old coconut garden during summer 2013. The experiment was laid out for evaluation of Difenacoum(0.005%) wax blocks with three replications. The pre-treatment data on treatment plots indicated an RI ranging from 17 to 23/ha (Mean: 19.66/ha) and per cent of nut damage varied from 6.71 to 8.88 (Mean: 8.14)(Table 13). The observations after 15 days of imposing treatments revealed that there was 100% control in number of trees infested with rodents as well as in nut damage even with first pulse of application of difenacoum(0.005%) wax blocks baits, whereas, in control plots the RI as well as nut damage registered an increasing trends.

Second season trial: This trial was undertaken in coconut garden (Arasikere tall variety) of Horticultural Research station, Arasikere, Hassan District, Karnataka during March – April, 2014. The coconut is grown mostly as mono crop and aged about 20 years grown on sandy loamy soil. The crop was given irrigation only during summer. The rodent species recorded in the garden were *Rattus rattus, Bandicota bengalensis and Finambulus palmarum*. There were four treatments including control. Before the application of bait the rodent infested trees and nut damage (%) was worked and 20g of bait was placed at the crown region of the coconut. The results of difenacoum(0.005%) revealed that the number of trees damaged by rodents (RI)

ranged from 24 to 27 per cent (Mean: 26.06%) and per cent of nut damage varied from 12.72 to 16.36 (Mean: 14.84%) at pre control stage. The observations after 15 days of imposing treatments revealed that there was 100% control in number of trees infestation as well as in nut damage by rodents even with one pulse of application of difenacoum baits.

Table.13. Efficacy of difenacoum and flocoumafen against rodents in coconut

2012-13		**Difenacoum**				**Flocoumafen**				**Control Mean**
		R1	**R2**	**R3**	**Mean**	**R1**	**R2**	**R3**	**Mean**	
Pre Control Census	Rodent Infested trees (RI)	23	17	19	19.66	20	16	18	18.00	19
	Coconut Damage (%)	8.84	6.71	8.88	8.14	7.28	5.36	8.76	7.13	7.34
Mid Control Census	Rodent Infested trees (RI)	0	0	0	0	0	0	0	0	20.33
	Coconut Damage (%)	0	0	0	0	0	0	0	0	8.94
Final control success (%)		100	100	100	100	100	100	100	100	109.01
2013-14										
Pre Control Census	Rodent Infested trees (RI)	24.54	27.27	26.36	26.06	27	28	21	24.33	27.61
	Coconut Damage (%)	16.36	15.45	12.72	14.84	15	15	14	14.67	14.92
Mid Control Census	Rodent Infested trees (RI)	0	0	0	0	0	0	0	0	28.17
	Coconut Damage (%)	0	0	0	0	0	0	0	0	15.22
Control success (%) with first pulse baiting		100	100	100	100	100	100	100	100	7.30

- *Mid census was done after 15 (Fifteen) days of first pulsing / application.*
- *Final census was done 15 (Fifteen) days after second pulse application*

(iv) Soybean: The bioefficacy of difenacoum(0.005%) wax blocks was evaluated against rodent pests in Soybean during kharif, 2013. The pattern of damage is highly variable within a field cutting of branches and sometime whole plant will be lodged due to cutting of main stem and pluck the tender pods and feed upon them besides hoarding of seeds and pods in their burrows. The predominant species associated with soybean were *Bandicota bengalensis, Millardia meltada* and *Tatera indica*.

The results indicated that the pre control census of was from 69 to 76 LBC/ha with a mean of 72.33 per replication. 7 days after 1st application of difenacoum(0.005%) wax blocks, the live burrow number was reduced to 26.66. Similarly after 2nd application the LBC was 9.66. Bromadiolone(0.005%) bait treated plots recorded an average burrow number of 67, 27.33 and 10.33, at pre-treatment, after first and second pulse application respectively. Overall control success was 63.76 and 62.20% with difenacoum(0.005%) and bromadiolone bait, respectively. In case of untreated control the active burrow count was marginally increased.

The mean pod damage at pre control stage was recorded as 7.5 per cent which was reduced to 2.5% in 14 days after first pulse of difenacoum(0.005%) treatment and further reduced to 1.26% after second pulse. The control success ranged from 66.66 per cent after first pulse application and 49.60 after second pulse application (Table 16). Similarly the per cent damage reduction with bromadiolone bait was 63.39 and 42.39 with first and second pulsing, respectively. The overall control success recorded was 60.56% with difenacoum and 50.16% with bromadiolone application.

3.3. FIELD TRIALS WITH FLOCOUMAFEN

(i) Coconut: The bioefficacy of Flocoumafen(0.005%) wax blocks was evaluated during 2013 and 2014 in coconut for two seasons.

First season trial was under taken at ZARS Mandya in about 20 years old coconut garden during summer 2013. The rate of rodent infested trees (RI) before treatment ranged from 18 to 20/ha (average of 18.00/ha) and nut damage varied from5.36to 8.76 % with an average of 7.13%. The observations after 15 days of treatment revealed 100% rodent control success. In the untreated plots the RI was 19 and 20.33 during the same time with increase in the nut damage of 7.34 to 8.94 per cent.(Table 13)

Similar results were obtained during second season trials undertaken in coconut garden (Arasikere tall variety) of Horticultural Research station, Arasikere, Hassan District, Karnataka during March – April, 2014.The rodent species recorded in the garden were *Rattus rattus, Bandicota bengalensis and Funambulus palmarum*.. The results revealed that the number of rodent infested trees (RI) ranged from 21 to 27 with an average of 24.33 and nut damage ranged from14to 15% with an average of 14.67%. The observations after 15 days of imposing treatments revealed that there was 100% control in number of trees and damage by rodents. The untreated plots had an RI of 27.61 and nut damage of 14.92 per cent. This has increased to 28.17 and 15.22%, respectively.

(ii) Rice: During the first season trial the flocoumafen(0.005%) was evaluated at Kallugopahalli near Bidadi of Ramanagaram District, Karnataka during summer 2013. The pre control census in case of treatment plots indicated that the live burrow count ranged from 32 to 37/ha and the damage incidence ranging from 3.00 to 3.60 per cent. After 15 days of treatment, the results revealed that Flocomafen (0.005%) reduced the live burrow counts ranging from 09 to 12/ha. with an average of 11.00 LBC/ha and the tiller damage ranged from 0.75 to 1.20 with an average of 1.02 (Table 14). The rodent control success with 1stpulse of rodenticide recorded a reduction of 69.56 LBC and 70.08% of incidence over pre control census. Rodent incidence after the application of second pulse revealed that the live burrows ranged from 3-4/ha with an average of 3.33 and tiller damage ranging from 0.25 to 0.34 per cent with an average of 0.30 per cent. Similarly final control success recorded a reduction 90.71% LBC and 90.695% of tiller damage over pre control census (Table 14).

Table 14. Bioefficacy of flocumafen (0.005%) wax cake against rodent pests in Summer rice, 2013 (Season-I)

		Flocoumafen				Control			
		R1	R2	R3	Mean	R1	R2	R3	Mean
Pre Control Census	No of burrows	32.0	39.00	37.00	36.00	35.00	3.00	4.00	3.66
	Damage incidence (%)	3.00	3.50	3.60	3.37	3.20	3.60	3.70	3.50
Mid Control Census	No of burrows	9.00	12.00	12.00	11.00	39.00	41.00	42.00	40.66
	Damage incidence (%)	0.75	1.10	1.20	1.02	3.60	3.70	4.00	3.77
Final Control Census	No of burrows	3.00	3.00	4.00	3.33	62.00	59.00	67.00	62.66
	Damage incidence (%)	0.25	0.31	0.34	0.30	5.30	5.20	5.50	5.33
Success with first pulse (%)	No of burrows	71.87	69.23	67.57	69.56	111.12	107.89	113.51	110.94
	Damage incidence	75.00	68.57	66.66	70.08	112.50	102.78	108.11	17.79
Final control success (%)	No of burrows	9.62	92.31	89.19	90.71	177.14	155.26	197.05	17.49
	Damage incidence	91.66	91.14	90.55	90.95	165.62	144.44	148.64	12.90

The second season trials were conducted in the farm area of Regional Agricultural Research Station, Mandya during Rabi 2013-14. The data indicated that the pre control census of LBC was 98.33/ha, whereas 7 days after 1stpulse, the LBC was reduced to 28 per hectare and 7/ha one week after second pulse. In case of untreated control the LBC was marginally increased from 104 to 107 per hectare (Table 15). The overall control success with burrow count and tiller damage incidence ranged 72.08 and 68.53%, respectively, while with bromadiolone (0.005%) the control success was s 67.63 and 62.06%, respectively.

(iii) Soybean: The bio efficacy of Flocomafen (0.005%) was evaluated in Soybean during kharif, 2013. The predominant species associated with soybean in experimental plot were *Bandicota bengalensis*, *Millardia meltada* and *Tatera indica*. The observation on live burrow count per hectare and per cent incidence by damage was recorded before imposing the treatments and after 1st and 2nd application of treatments. The result indicated that the pre control census of LBC ranged from 65 to 72/ha (Mean: 68.35), whereas 7 days after 1st application the LBC were reduced to 23 to 25/ha (Mean: 24.0). Similarly after 2nd application the LBC were 6 to 8/ha (Mean: 7.0). In case of untreated control the LBC was marginally increased (Table 16).

Table 15. Bioefficacy of flocumafen (0.005%) wax cake against rodent pests in kharif rice, 2013 (Season-II)

		R 1	Br 1	R 2	Br 2	R 3	Br 3	Mean for R	Mean Br.	Control
Pre control	Rate of infestation No. of burrows)	95	105	102	102	98	89	98.33	98.66	101.66
	Damage incidence	7.42	4.42	7.09	4.32	7.06	4.41	7.19	4.38	7.22
Mid control	rate of infestation No. of burrows)	24	34	29	32	31	29	28.00	31.66	104.00
	Damage incidence	2.26	2.50	2.12	2.27	2.31	3.02	2.33	2.59	7.61
Final control	Rate of infestation(No. of burrows)	7	9	8	10	8	12	7.66	10.33	107.00
	Damage incidence	0.71	1.07	0.77	0.90	0.70	1.12	0.72	1.03	8.23

Control success After 1 pulsing (%)	Rate of infestation(No. of burrows)	-	-	-	-	-	-	71.52	67.90	-
	Damage incidence	-	-	-	-	-	-	68.84	64.13	-
Control success After II pulsing (%)	Rate of infestation(No. of burrows)	-	-	-	-	-	-	72.64	67.37	
	Damage incidence	-	-	-	-	-	-	68.22	60.00	
Overall Control Success (%)	Rate of infestation(No. of burrows)	-	-	-	-	-	-	72.08	67.63	
	Damage incidence	-	-	-	-	-	-	68.53	62.06	

Table 16. Bioefficacy of difenacoum (0.005%) & flocumafen (0.005%) wax cake againstrodent pests in Soybean during Kharif, 2013

		Difenacoum Mean	**Bromodiolone Mean**	**Flocoumafen Mean**	**Control**
Pre control	Rate of infestation (No. of burrows)	72.33	67.00	68.33	70.66
	Damage incidence	7.51	7.54	7.45	7.26
Mid control	rate of infestation(No. of burrows)	26.66	27.33	24.00	7.26
	Damage incidence	2.50	2.76	2.44	73.00
Final control	Rate of infestation(No. of burrows)	9.66	10.33	7.00	76.68
	Damage incidence	1.26	1.59	0.90	75.66
Control success After I Pulse (%)	Rate of infestation(No. of burrows)	63.14	59.21	64.87	3.19
	Damage incidence	66.66	63.39	67.24	-
Control success After II pulse (%)	Rate of infestation(No. of burrows)	63.76	84.58	89.75	-
	Damage incidence	49.60	78.91	87.92	-
Overall Control Success (%)	Rate of infestation(No. of burrows)	87.23	71.89	90.74	7.14
	Damage incidence	60.56	71.15	71.78	8.23

(iv) Storage: The results of first season trial (Table 17) indicated that the average tracking index during pre-control census was 199.99 in treatment store and 211.11 in control. However, after 15 days of treatment the control success was 74.05 % reduction while in control there was increase in rodent population (10.51) when compared with pre-treatment population. With the second application of the flocoumafen, the control success was 96.45 per cent with tracking index. The efficacy of new rodenticide against rodents with tracking activity method (Table 17) indicated 96.45 per cent after IInd dose with tracking activity index (TAI) was 7.41 with first application of the rodenticides.

The results in the second season also indicated similar results. After application of first pulse, the bait consumption varied between 64 to 78 g in an average of 72.33 g/day and the number of burrow and trapping index reduced to 4.66 to 2.44 respectively. After application of second pulse, the average consumption of bait, number of burrows and trap index further reduced to 53g/day, 3.00 and 1.55 respectively. The control success by trapping index with mid control and final control was 78.01% and 86.03% respectively (Table18).

Table 17. Efficacy of flocoumafen (0.005%) against commensal rodents inStorage (Season-I)

	Tracking activity			Mean	Control	Mean	Control
	R1	R2	R3				
Pre treatment	188.88 (17)	233.33 (21)	177.77 (16)	199.99 (18)	211.11 (19)	192.59 (17.33)	199.99 (18)
10 days after Ist pulsing	144.44 (13)	166.66(15)	133.33 (12)	148.11 (13.33)	222.22 (20)	122.22 (11.00)	211.11 (19)
Control Success after Ist pulse (%)	76.47	71.42	75.00	74.05	10.52	61.11	5.55
10 days after IIndpulse	11.11 (1)	11.11 (1)	0.00 (0)	7.41 (0.66)	222.22 (20)	29.67 (2.67)	222.22 (20)
Final Control Success (%)	94.12	95.24	100.00	96.45	10.52	84.74	11.11

Figures in parenthesis indicates the actual tracking numbers on three tiles (15 X 5 cm) for three nights.

Table 18. Efficacy of flocoumafen (0.005%) against commensal rodents in Storage (Season-II)

		Flocoumafen				**Control**			
		R1	R2	R3	Mean	R1	R2	R3	Mean
Pre Control Census	No. of burrows	21.00	20.00	18.00	19.66	22.00	21.00	20.00	21.00
	Trap index	13.33	12.66	7.33	11.10	12.33	11.66	9.33	11.10
Mid Control Census	Census bait consumed (g)	78	75	64	72.33	-	-	-	-
	No. of burrows	5	4	5	4.66	22	23	24	23
	Trap index	3.66	2.33	1.33	2.44	10.66	9.33	8.66	9.55
Final Control Census	Census bait consumed (g)	20	18	15	53.00	-	-	-	-
	No. of burrows	4	2	3	3	24	25	21	23.33
	Trap index	2.33	1.33	1.00	1.55	9.33	10.33	9.33	9.66
Control Success with I pulse (%)		70.79	81.59	81.85	78.01	-	-	-	-
Final control success (%)		82.52	89.49	86.35	86.03	-	-	-	-

Comparative efficacy (% success control) of Difenacoum and Flocoumafen trials/treatments against rodents in various crops are given in Table 19. It was 100% in coconut; 91.01% in Paddy (Kharif); 79.35% in summer; 73.89% in Soybean crop; 85.76% in storage; due to Difenacoum and 100% in coconut; 91.97% paddy, (Kharif); 90.83% (summer); 81.26% in soybean; 83.24% in storage due to flocoumafen application, (average of all evaluation methods).

Table 19. Comparative Efficacy of difenacoum and flocoumafen against rodents in various situations (Average)

Crops	**Locations**	**Mortality (%)**		
		Difenacoum	**Flocoumafen**	**Control**
Coconut	Ist season	100.00 (RI) 100.00 (Incidence)	100.00 (RI) 100.00 (Incidence)	23.74 15.82
	IInd Season	100.00 (RI) 100.00 (Incidence)	100.00 (RI) 100.00 (Incidence)	4.57 12.90
Rice	Summer	79.07 (burrow) 79.64 (Incidence) 79.35	90.71 (burrow) 90.95 (incidence) 90.83	17.49 12.90
	Kharif	91.16 (burrow) 90.87 (Incidence) 91.01	92.84 (burrow) 91.11 (incidence) 91.97	5.94 12.06
soybean		87.23 (burrow) 60.56 (incidence) 73.89	90.74 (burrow) 71.78 (incidence) 81.26	7.14 8.23
Storage	Trapping index method	86.78 85.76	86.03 83.24	
	No. of burrows	84.74	80.46	

4. DEVELOPMENT OF RODENT MANAGEMENT TECHNOLOGIES FOR RURAL STORAGE CONDITIONS

In order understand the storage losses due to rodents and their effective managements, studies were carried out at farmer's houses in Sulivara and Mayasandra villages during 2012-13 in paddy and ragi storage structures. The storage structures of small farmers comprised of gunny bags, mud and metal bins for storing food grains. The experiment was designed with six treatments in three replication. (T_1 – snap trap, T_2- Glue trap, T_3- Wonder trap, T_4-Box trap, (single catch), T_5- Modified snap trap, T_6-untreated control). The storage loss and the population of rodents were estimated before setting the traps using chalk powder in the path of rodents on the basis of foot prints. Totally four of each traps were placed in paddy and ragi storage areas for 10 days.

The trapping data showed that the rodent pests were *Rattus rattus* and *Mus musculus*, their population range was 15 to 19 and storage loss of 165 to 200gm paddy per day. The trapping results indicated that wonder trap (71.14%) were superior followed by glue traps (69.98%), snap trap (66.86%) and the storage loss were reduced to 45 to 85gm. The results of ragi storage structures at Mayasandra village houses, were on par with paddy storage structures (Table 20&21).

Table 20: Evaluation of various traps for management of rodents in rural storage structure (Rice) at Sulivara for the year 2012-13

Traps type	Pre treatment	Loss in Paddy (g/day)	After treatment				Per cent Reduction	
	No. of Rats		Rr	Mm	Total	Grain Loss (g/day)	Rats	Paddy
Snap trap	15.33	165.0	2.33	3.66	6.00	75	66.86	44.45
Glue trap	16.66	180.0	2.66	2.33	5.00	45	69.98	75.00
Wonder trap	17.33	185.0	3.33	4.66	5.00	80	71.14	56.75
Box trap (single catch)	18.33	205.0	3.66	2.33	6.00	65	67.26	68.29
Modified snap trap	19.33	250.0	3.66	3.66	7.32	85	62.13	66.00
Untreated control	17.66	190.0	-	-	18.66	200	5.66	5.26

Table 21: Evaluation of various traps for management of rodents in rural storage structure (Ragi) at Mayasandra for the year 2012-13

Traps type	Pre-treatment Population	Loss in Ragi (g/day)	After treatment				Per cent Reduction	
	No. of Rats		*Rr*	*Mm*	Total	Grain Loss (g/day)	Rats	Ragi
Snap trap	16.33	177	1.33	4.66	6.00	65	63.25	63.27
Glue trap	20.66	216	2.66	2.33	5.00	57	75.79	73.61
Wonder trap	17.33	192	2.66	2.66	5.32	70	69.30	63.54
Box trap (single catch)	20.00	223	3.66	4.33	8.00	80	60.00	64.12
Modified snap trap	21.33	259	2.66	3.66	6.32	70	70.37	72.97
Untreated control	17.66	199	14.33	4.33	18.66	210	5.66	5.52

5. BIO ECOLOGY OF *BANDICOTA INDICA*

5.1. Morphometry of field collected Larger Bandicoot, *Bandicota indica*

Six males and six female adults of larger bandicoots were collected from the open area in Bangalore indicated that the females were larger than their males. The mean body weight of male was 593.58 g with a range of 285.0 to 1203.0 g while that of female weight was 857.63 g with a range of 613.5 to 892.5 g. However the overall range varied from 285.0 to 1210.0 g (Table 22). Even body length (cm), Ear length (cm), Front leg length, ear leg length (cm) and

Tail length were comparatively more in field collected females than males. However, even after 2 years of their rearing in separate room (12' X 12') with 2 males and 2 females together, with sufficient food/vegetables and water, there was no breeding activity. This clearly indicates that the breeding activity of *B. indica* does *not* take place in the presence of human activities. For this purpose a hidden separate chamber may be constructed to study the biology and breeding activity of rodents.

Table 22. Body weight and Morphometry of field collected *Bandicota indica*

Sex	Sl. No.	Body weight (g)	Body length (cm)	Ear length (cm)	Fore foot length (cm)	Hind foot length (cm)	Tail length(cm)
Female	1	882.5	29.6	2.30	6.50	11.50	28.60
	2	758.3	26.0	2.00	7.10	10.75	25.50
	3	613.5	23.5	2.20	6.30	8.75	31.90
	4	892.5	31.7	2.30	6.50	9.80	32.50
	5	789.0	28.2	2.10	6.80	11.00	34.50
	6	1210.0	37.00	2.80	7.60	10.50	29.50
Mean		**857.63**	**29.33**	**2.28**	**6.80**	**10.38**	**30.42**
Male	1	480.50	24.60	2.30	5.90	9.30	23.00
	2	595.5	25.30	1.80	5.35	8.70	24.60
	3	285.0	22.30	1.90	6.25	9.35	28.50
	4	441.5	24.00	2.20	5.80	7.75	24.80
	5	556.0	27.50	2.20	6.50	8.00	25.50
	6	1203.0	36.50	2.70	6.60	9.20	31.00
Mean		**593.58**	**26.70**	**2.18**	**6.07**	**8.72**	**26.23**
Range		285.0-1210.0	22.30-37.00	1.80-2.80	5.35-7.60	7.75-11.50	23.00-34.50

5.2. Laboratory feeding behaviour and observations on breeding aspects

laboratory studies on *B. indica,* maintained in the animal house revealed that they were very fierce and accepted all types of food, vegetables, cereals, pulses, oil seeds, their daily intake varied from 12.5 to 35gm Ragi, 14.4 to 42gm jowar and 13.70 to 38gm rice when fed separately. Feeding on these baits, they showed increase in their body weights, average male weighed 503.58 and female 857.63, with a body length of 28.56cm males being higher than females (26.15cm). Even after two years of rearing in the laboratory, there was no indication of breeding by the female bandicoots.

5.2. Studies on population of *B. indica* in urban locales of Bangalore

Studies were conducted to know the activity of *B. indica* in and around parks / gardens of Bangalore. The data on trapping index indicated that their activities were noticed throughout year in all the three parks. The maximum (8.33 trap index) was seen during April followed by January, February and March (7.78) respectively. The adult Bandicoots were trapped maximum during January and April with a range of 7.22 to 8.33 trap index (Table 23).

Table 23. Monitoring of *B. indica* urban areas (parks) of Bangalore (2013-14)

Month	Park 1	Park 2	Park 3	Mean
April	8.33 (5.0)	8.33(5.0)	8.33(5.0)	8.33(5.00)
May	8.33 (5.0)	8.33(5.0)	3.33(2.0)	6.66(4.00)
June	6.67 (4.0)	5.30(3.0)	3.33(2.0)	5.00(3.00)
July	1.67 (1.0)	0.00(0.0)	1.67(1.0)	0.56(0.67)
August	3.33 (2.0)	1.67(1.0)	5.00(3.0)	3.33(2.00)
September	3.33 (2.0)	3.33(2.0)	3.33(2.0)	3.33 (2.00)
October	5.00 (3.0)	3.33(2.0)	6.67(4.0)	5.00(3.00)
November	5.00 (3.0)	3.33(2.0)	5.00(3.0)	4.00(2.67)
December	6.67 (3.0)	5.00(3.0)	5.00(3.0)	5.56(3.33)
January	8.33 (5.0)	6.67(4.0)	6.67(4.0)	7.22(4.33)
February	6.67 (4.0)	6.67(4.0)	10.00(6.0)	7.78(4.67)
March	8.33 (5.0)	8.33(5.0)	6.67(4.0)	7.78(4.67)
Mean	5.97 (3.50)	5.00(3.00)	5.42(3.42)	-

Figures in parenthesis indicates actual number trapped (20 traps for 3 nights).

6. DEVELOPMENT AND REFINEMENT OF RODENT PEST MANAGEMENT MODULES IN PREDOMINANT CROPS/ CROPPING SYSTEMS

The studies were conducted at Thagachaguppe village, in MagadiTq of Ramanagara District of Karnataka, during 2012-13, both in kharif as well as in summer. The study indicated five rodent species were associated with the groundnut crop. They were *B. bengalensis*, *T. indica, Mus booduga, Mus platythrix & B. indica.*

6.1. Burrowing pattern

The burrows of *B. bengalensis* were clearly marked by the presence of heaps of soil at different points along the burrow length in the form of 'mole hills'. The mean weight of soil excavated 5.55 ± 3.1kg. The burrow opening of *T. indica* was without cover by the excavated soil. The burrows of *M. booduga* were simple and shallow could be ascertained by the degree of freshness or wetness of pellets at the entrance. *M. platythrix* exhibited a peculiar behaviour of pebble collection around the surface openings. The mean number and mean diameter of side tunnels seen during the cropping seasons and off season were 3.36 ± 1.01 and 7.07 ± 0.77 cm for *B. bengalensis* and 2.13 ± 0.54 and 3.61 ± 0.30 for *T. indica*. The mean number tunnels in *M. booduga and M. platythrix* was 0.5 ± 0.92 and mean diameter of tunnel was 2.53 ± 0.20 and 2.35 ± 0.18 for respective species. However for *B. indica* mean number of tunnels was 3.37 ± 0.25 with a mean diameter of 12.75 ± 0.35 cm. Maximum depth of the burrow of *B. indica* was 112.5cm followed by B. *bengalensis*(89cm), *T. indica* (44 cm), *M. booduga(*18cm) and. *platythrix*(38.6cm).Likewise total length of burrow was recorded in case of *B. Bengalensis* (753cm), *T. indica* (390cm) *M. booduga,* (35-129 cm) and *M. platythrix (*75-145cm).*B. bengalensis* hoarded 36.24gm/ burrow, and gerbil also hoarded 52.09 ±56.45g groundnuts especially in summer. Whereas, *M. booduga* and *M. platythrix* did not hoard any materials expect few leaves and straw of the neighboring crops.

6.2. Evaluation of rodenticides in different treatments and snap traps in groundnut crop

Following 13 treatments (including traps, rodenticides and fumigants in various combinations with one control) treatments were imposed in groundnut crop fields for developing rodent management modules. They are: **T1:**Setting 54 Snap traps per ha at germination stage; **T2**: Zn3P2 (2%) baiting at germination stage; **T3**:Bromadiolone CB (0.005%) at germination stage; **T4**: ALP application in burrows at germination stage; **T5**: Setting 54 Snap traps per ha at peg formation stage; **T6:** Bromadiolone CB (0.005%) at peg formation stage; **T7**:Zn3P2 (2%) baiting at peg formation stage; **T8**: ALP application in burrows at peg formation stage; **T9:**T1+T7; **T10**: T3 + T7 ; **T11**:T2 + T8; **T12**: T2 + T6 and **T13**: Untreated Control.

The results obtained in various treatments are presented in Table 24. The cost benefit ratio was higher 1:36.56 in T7 (2% Zinc phosphide baiting at peg formation stage with yield 1239.11kg/ha) followed by T8 (Aluminum phosphide application in summer at peg formation stage) and T6 (Bromodiolone (0.25%) at peg formation stage with 1:30.88 and 1:28.6 with a yield of 1264.06 and 1190.19 kg/ha respectively.

Table 24. Evaluation of rodent management strategies in groundnut field during summer season

Treatment	% Reduction in LBC	Yield kg/ha	CB Ratio
T1 Setting 54 Snap traps per ha at germination stage	24	998.14j	1:2.23
T2: Zn3P2 (2%) baiting at germination stage	30	1089.00i	1:20.39
T3:Bromadiolone CB (0.005%) at germination stage	24	979.68k	1:7.82
T4: ALP application in burrows at germination stage	42	1141.01h	1:20.45
T5: Setting 54 Snap traps per ha at peg formation stage	60	1211.30f	1:8.71
T6: Bromadiolone CB (0.005%) at peg formation stage	54	1190.19g	1:28.61
T7:Zn3P2 (2%) baiting at peg formation stage;	63	1239.11e	1:36.56
T8 Aluminum phosphate application in burrows	72	1264.06 d	1:30.88
T9: 54 Snap traps/ha + 2% Zinc phosphide	74%	1328.17b	1:9.83
T10: Bromadiolone CB (0.005%) at germination + 2% ZnP	72	1283.21cd	1:4.10
T 11: 2% Zinc phosphide baiting and AlP fumigation	76	1351.33a	1:21.44
T 12: 2% Zinc phosphide + Bromadiolone CB (0.005%)	72	1308.00c	1:21.09
T13: control	-	900.31	-
SEM		17.05	
CD		49.76	

7. SOCIAL ENGINEERING ACTIVITY ON RODENT PEST MANAGEMENT AS PARTICIPATORY ADAPTIVE RESEARCH IN ADOPTED VILLAGES

During 2012-13 and 2013-14, the project was implemented in the three villages- Koramangala, Bijwara and Awati of Chikkaballapura District of Karnataka. In Koramangala, all the inputs (Information, demonstration, rodenticide, baits/ anticoagulants) were made available, in Bijwara, no inputs were made available except the information on rodent management, training and demonstrations and in Awati, neither inputs nor information demonstration/ training were given. It was a control village. Prior to the start of implementations, basic knowledge, KAP with other informations on Rodent pest aspects and crop details in villagesamong the farmers were collected through questionnaires.

In order to evaluate the impact of the project implementation, 7 plots in varied crops (Ragi, Beans, Cabbage, Potato, cowpea, Paddy, Grapes) 1 ha each was selected in all the villages and rodent damage (LBC/ha) and rodent incidence (%) were recorded before the rodent control operation involving the farmers.

The results of the study during 2012-13 of the KAP analysis showed that the farmers of Koramangala, the knowledge on rodents (47.50 to 84%), the attitude (54 to 91%) and Practices (44 to 89%) improved from primary adaptors to innovators and moderate to high respectively after 21 days of implementation (Table 25).

In Awati, the knowledge aspects improved from moderate (45%) to high (78.50%), the attitude (56 to 72%) and practices (43 to 75%), highlighting that they need demonstrations and farmers interaction. While in Bijwara both knowledge (45 to 55%) and practices (53 to 55%) were improved from low to moderate, but Attitude wise, they remained as secondary adaptors (47%), thus, the farmers of Bijwara require complete package stage of social engineering that is, demonstrations, farmers interaction, and operational skills.

On the other hand, control rodent operations in fields have registered a significant reduction in rodent density in crop fields in koramangala village that is 78.32% reduction in rodent density and 79.24%, reduction in their incidence at crop harvest. In Awati, It was 24.68% and 21.6% and in Bijwara, there was an increase in rodent density (54%) and incidence (50.23%) respectively, during crop harvest stage. The rodent density increased by twice (103.57) and incidence by almost thrice (141.25).

During 2013-14, the results revealed that after successive two years of project implementation, there was a reduction of rodent density and rodent infestation by 78.43% and 73.73% after 21 days and 80.62% and 77.05% during harvest in Koramangala village. While in Bijwara the reduction was only 71.74% and 71.44% and in Awati, there was an increase of 21.93% and 21.92% in rodent density and rodent incidence (Table 26).

Among the KAP data knowledge, Attitude and Practices reached 41.5% to 81%, 57 to 93% and 41 to 87, indicating an enormous increase in KAP, while in Bijwara, the increase registered was 41 to 87, 43 to 75.7 and 51 to 70%, respectively. However in village Awati, the KAP figures were sedentary increase from44 to 45% in knowledge, 44 to 45% in attitude and 51 to 52% in practices indicating that there was not much change with regard to adaptation of rodent management practices (Table 27).

During 2014-15 the studies on Social Engineering Activity was taken up in Ramanagara district about 50 kms from Bangalore. The villages selected were Chowdeswarihalli (Maintenance given all the inputs), Nagohalli (Neglected – only information) and Kukkur (control-no information and inputs).The general information of the villages are given in Table 28.

The results were again very promising and indicated that in Chowdeswarihalli, reduction of 78.79% in rodent density and 82.14% rodent infestation after 21 days of treatment and at harvest the figures were 80.48% and 83 to 39% respectively in Paddy, Ragi, Cowpea, Food crop fields. In Nagohalli it was only 21.23% and 22.87%. While in Kukkur, there was an increase in rodent density by 19.28% and rodent infestation by 21.86% highlighting the fact that transfer of rodent pest management is absolute necessary (Table 29).

The KAP analysis indicated that the farmers of Chowdeswarihalli had higher knowledge level (83%)s, Practices (92.5%) and Attitude (53%) when compared with Nagohalli, with 9.39 to 85%, KAP score and Kukkur village farmers remained second adopters with low score indicating the need for extension intervention (Table 30).

Table 25. Social Engineering Activity on rodent control in villages: Socio economic strata for the villages under farmer's participatory approach during 2012-13

Koramangala (Information and materials supplied)			**Measures to be taken up**
	Initial level	After 21 days	Media & Publicity
Knowledge	47.50% - Low	84.00% - High	
Attitudes	54.00% - Sec. adopters	91.00% - Innovators	
Practices	44.00% - Low	89.00% - High	
Avati (only information)			
Knowledge	45.00% - Low	78.5% - Moderate	Demonstrations, farmers interaction
Attitudes	56.00% - Sec. adopters	72.0% Sec. Adopters	
Practices	43.00% - Low	75.00% - Low	
Bijwara (control)			
Knowledge	48.00% - Low	55.00% - Moderate	Demonstrations & Farmers interaction
Attitudes	53.00% - Sec. Adopters	55.00% - Sec. adopters	
Practices	47.00% - Low	47.00% - Low	

Table 26. Rodent density and incidence by rodents at three villages under farmer's participatory approach (Social engineering activities) 2013-14

Village	Plot No	Crop	Rodent density (LBC/ha)			Rodent infestation (%)		
			Pre treatment	After 21 days	During harvesting	Pre treatment	After 21 days	During harvesting
koramangala	1	Ragi	42	15	12	5.60	1.13	0.96
	2	Ragi	47	9	8	5.82	1.22	1.10
	3	Grapes	34	9	7	6.10	1.52	1.20
	4	Ragi	51	8	6	6.40	1.06	1.12
	5	Groundnut	55	11	12	6.35	1.32	0.85
	6	Cabbage	39	7	6	4.90	1.45	1.20
	7	Potato	52	10	11	4.80	1.60	1.32
	Mean		45.71	9.86	8.86	5.71	1.33	1.11
Per cent / over pre treatment				78.43	80.62	-	73.73	77.05
Bijwara	1	Ragi	39	32	39	5.10	4.13	4.80
	2	Grapes	27	22	20	3.89	2.99	32.5
	3	Potato	59	44	45	6.78	5.42	4.90
	4	Ragi	45	40	44	5.40	5.50	5.10
	5	Beans	36	29	25	4.61	3.27	3.45
	6	Cabbage	44	37	37	5.02	4.17	4.56
	7	Cabbage	49	42	45	5.35	4.33	4.75
	Mean		42.71	35.14	36.42	5.16	4.23	4.40
Per cent / over pre treatment				17.72	3.64	-	17.44	3.28
Avati	1	Beans	41	43	53	4.42	4.44	6.50
	2	Grape	34	37	48	3.67	3.82	4.90
	3	Ragi	47	47	55	5.26	5.29	6.38
	4	Ragi	49	53	59	5.27	5.35	5.47
	5	Groundnut	65	70	75	6.72	7.30	7.58
	6	Ragi	54	55	63	6.30	6.80	7.82
	7	Ragi	43	48	53	4.81	4.89	6.13
	Mean		47.57	50.42	58.00	5.21	5.41	6.40
Per cent / over pre treatment			-	21.92	21.92	-	3.84	23.03

Table 27. Influence of extension intervention on KAP of rodent control (2013-14)

Village	Parameter	Levels of KAP before and after extension intervention				
		Initial level	Remarks	After 21 days	Remarks	Measure to be taken
Koramangala	Knowledge	41.50 %	Low	81.00 %	High	Media and publicity
	Attitude	57.00 %	Secondary adopters	93.00 %	Innovators	
	Practices	41.00 %	Low	87.00 %	High	
Bijvara	Knowledge	43.00 %	Low	72.50 %	Low	Demonstrations, farmers interaction
	Attitude	51.00 %	Secondary adopters	70.00 %	Secondary adopters	
	Practices	40.00 %	Low	71.00 %	Low	
Avati	Knowledge	44.00 %	Low	45.00 %	Low	Demonstrations and farmers interaction
	Attitude	51.00 %	Secondary adopters	52.00 %	Secondary adopters	
	Practices	48.00 %	Low	48.00 %	Low	

Table 28. General information of social engineering villages

Sl. No.	Name of the village	Choudeshwarihalli	Nagohalli, Kailanchhobli, Ramanagara (Tq.), RamanagaraDist	Kukkur MalurHobli Channapattana (Tq.) Ramanagara Dist.
1	Total population	450	521	449
2	Total house holders	104	117	102
3	Total area under cultivation	245	91	76.8
4	Total area under irrigation	194.8	68	32.0
5	Total No. of land holders	98	105	102
6	Major crop grown during the year	Ragi coconut, paddy, vegetable, cowpea	Paddy, Ragi, Sorghum, Fodder, Mango, Banana, coconut etc.,	Ragi, Sorghum, Tur, Paddy, Pulses, Fodder, Coconut
7	Allied Agricultural activities	Dairy, Sericulture, Poultry, Sheep rearing	Sericulture, Dairy, Poultry, Sheep rearing	Sericulture, Dairy, Poultry, Sheep rearing

Table 29. Rodent density and incidence by rodents at three villages under farmer's participatory approach (Social engineering activities) 2014-15

Village	Plot No	Crop	Rodent density (LBC/ha)			Rodent infestation (%)		
			Pre treatment	After 21 days	At Harvest	Pre treatment	After 21 days	During harvesting
Choudeswarihalli	1	Ragi	47	10	9	4.80	0.95	0.85
	2	Coconut	23	5	3	10.45	1.05	0.97
	3	Ragi	41	10	9	4.72	1.13	0.98
	4	Paddy	53	11	12	5.18	0.98	0.90

(RamanagaramTq.)	5	Ragi	39	9	7	4.62	0.83	0.81
	6	Cowpea	51	10	11	5.32	1.17	1.00
	7	Cabbage	43	8	7	4.11	0.95	0.98
	Mean		42.43	9.0	8.28	5.60	1.00	0.93
Per cent / over pre treatment			-	78.79	80.48	-	82.14	83.39
Nagohalli (RamanagaramTq.)	1	Paddy	53	43	55	5.13	4.05	5.80
	2	Ragi	47	36	53	5.05	3.88	6.98
	3	Ragi	59	45	62	5.86	4.39	6.26
	4	Paddy	49	39	48	4.96	3.91	6.10
	5	Coconut	27	21	32	9.36	6.92	7.90
	6	Ragi	41	37	48	4.35	3.56	5.85
	7	Cowpea	43	35	54	4.83	3.76	5.44
	Mean		46.43	36.57	50.23	5.64	4.35	6.33
Per cent / over pre treatment			-	21.23	8.18	-	22.87	12.23
Kukkur, (ChannapattanaTq)	1	Ragi	43	47	59	4.3	4.5	5.5
	2	Paddy	39	45	63	3.6	4.2	5.4
	3	Ragi	38	44	56	3.1	4.3	6.8
	4	Ragi	36	45	61	3.5	4.0	6.3
	5	Cowpea	29	34	52	3.3	4.2	5.6
	6	Fodder	31	39	47	2.6	3.7	4.1
	7	Paddy	33	43	57	3.6	4.4	6.4
	Mean		35.57	42.43	56.43	3.43	4.18	5.73
Per cent / over pre treatment			-	19.28	58.64	-	21.86	67.05

Table 30. Influence of extension intervention of rodent control on KAP inSocial Engineering villages (2014-15)

Village	Parameter	Levels of KAP before and after extension intervention				
		Initial level (%)	Remarks	After 21 days (%)	Remarks	Measure to be taken
Choudeswarihalli (RamanagaramTq.)	Knowledge	37.5	Low	83.0	High	Media and publicity
	Attitude	53.0	Secondary adopters	91.0	Innovators	
	Practices	42.0	Low	92.5	High	
Nagohalli (RamanagaramTq.)	Knowledge	39.0	Low	85.0	High	Training programme
	Attitude	56.0	Secondary adopters	85.5	Secondary adopters	
	Practices	45.0	Low	72.0	Low	
Kukkur, (ChannapattanaTq)	Knowledge	35.0	Low	36.0	Low	Demonstrations and farmers interaction
	Attitude	55.0	Secondary adopters	56.0	Secondary adopters	
	Practices	44.0	Low	47.0	Low	

LOCATION SPECIFIC PROGRAMMS

1. RODENT PROBLEMS IN POLYHOUSE AGRICULTURE AND DEVELOPMENT OF MANAGEMENT STRATEGIES

The studies was conducted at poly houses with carnation ornamental plants at flowering stage at Bettadabyrapura in Doddaballapura Taluk of Bangalore rural District during the three year study period. Initial/pre control rodent population was estimated using LBC count and rodent damage. The following treatments were carried out. In all five treatments viz., 1. Burrow fumigation with chilli powder 20g/ burrow; 2. Bromodiolone(0.005%) cake application 1pc/burrow; 3. Zinc phosphide 2% followed by Bromodiolone; 4. Snap traps at 1/30 sq.ft; 5. And Live trap at 1/30 sq.ft, The post control census was taken up after 10 days of application.

The major rodent pests involved were *B. bengalensis* followed by *M. booduga and T. indica*. During 2014-15, *Mus platythrix* was also trapped. The extent of damage to the flower plants in different years was 9.5-12.5% (2012-13); 10-11% (2013-14) and 7.5- 9.6% (2014-15). The highest per cent reduction in rodent activity mean control success of 79.76% was registered due to 2% Zinc phosphide followed by Bromadiolone, which was followed by use of snap trap @ 1/30 sq.ft, (66.96%); 61.34% by Bromadiolone application; 49.96% by Burrow fumigation. Rodent control success estimated through reduction in damage also followed the same trend with highest success (80%) with 2% Zinc phosphide followed by Bromadiolone (Table 31).

Overall analysis of proved superiority of integrating acute rodenticide (zinc phosphide 2%) with anticoagulant rodenticide (bromadiolone 0.005%) yield in a mean success of 79 to 80% success.

Table 31. Efficacy of rodent population's management technologies in poly house agriculture at Bettadabyrapur, Bangalore rural.

Sl No.	Treatments	Control success During 2012-13 based on		Control success During 2013-14 based on		Control success During 2014-15 based on		Mean Control success based on	
		Damage	Rodent density	Damage	Rodent density	Damage	Rodent density	Damage	Rodent density
1	Burrow fumigation with chili powder @ 20g/burrow	52.64	58.87	52.38	52.11	44.87	45.07	49.96	52.01
2	Bromadiolone cake @ 16g /burrow	63.41	63.40	46.34	52.31	74.28	72.88	61.34	62.86
3	Poison baiting with ZnP @ 2% followed by Bromodiolone	80.0	77.68	69.27	73.46	90.03	89.65	79.76	80.26
4	Snap trap @ 1/30 sqft	66.66	76.51	61.92	61.42	72.31	71.60	66.96	69.84
5	Live trap @ 1/30 sqft	40.48	39.30	50.70	50.74	-	-	45.59	45.02

Treatment only in 2012-13 and 2013-14.

2. MANAGEMENT OF RODENT PESTS IN GRAPE GARDEN UNDER DRIP IRRIGATION

Grape being commercially important Horticultural crop of Karnataka extensively used as fruit and in wine production. The studies were undertaken so as to work out the management strategies at Srirampura village in Chikkaballapura District. Five plots of one hectare each were selected and treatments were carried out. The rodent population was monitored using LBC/ha and per cent damage before and after the treatments.

The rodent pests infesting grape gardens were *Funambulus palmarum, Bandicota bengalensis, Millardia meltada, Mus booduga, Mus platythrix*. Fruit damage in grapes ranged between 7-8%. In all four treatments (Bromadiolone baiting; Snap trapping, zinc phosphide baiting and glue traps) were imposed in grape gardens of Sreerampura of Chikkballapura distt during 2012-13 1md 2013-14, whereas in third year combination treatment of zinc phosphide followed by bromadiolone baiting was also added.

During first year maximum reduction in rodent incidence due to treatments was noticed with Zinc phosphide, 2%baiting (74.16%), followed by snap trap @ 1/30 sq.ft and bromodiolone cake (0.005%) yielding 58.84 and 57.0%. Similar trend was recorded in terms of reduction in rodent damage i.e., 72.72, 60.0 and 51.85% respectively. During 2013-14 studies also repeated and the similar trend in control success was registered (Table 32). In the third year (2014-15), the combination treatment of zinc phosphide followed by bromadiolone baiting (imposed in this year only) proved the best yielding the highest control success of 88.64% (based on rodent incidence) and 89.31% (based on damage). Second best was single baiting with zinc phosphide (73.08 and 74.44% success with respective assessment methods). The performance of various treatments in various study years are detailed in Table 32.

Table 32: Rodent management in grape garden at Srirampura of Chikkabllapura

Sl No.	Treatments	Control success During 2012-13 based on		Control success During 2013-14 based on		Control success During 2014-15 based on		Mean Control successOf 3 years based on	
		Damage	Rodent density	Damage	Rodent density	Damage	Rodent density	Damage	Rodent density
1	Br.cake @ 16g /burrow	51.85	57.0	57.14	59.70	51.85	57.00	53.61	57.90
2	Snap trap @ 54/ha	60.0	58.84	62.0	61.10	60.00	58.84	60.00	59.59
3	Poison baiting with ZnP @ 2%	72.72	74.16	73.81	75.00	72.72	74.16	73.08	74.44
4	Glue trap @15 ft gap at (Borders only)	34.48	30.0	35.90	30.00	34.48	30.00	34.95	30.00
4	* ZnP followed by Br	-	-	-	-	89.31	88.64	89.31	88.64

* *Treatment only in 2014-15 (ZnP= zinc phosphide 2% and Br= Bromadiolone cake 0.005%)*

3. OPERATIONAL TRIALS ON TRUNK BANDING TECHNOLOGY FOR RODENT PEST MANAGEMENT IN COCONUT PLANTATIONS

Studies were conducted at Agricultural Research Station, Arasikere in coconut garden (20 years old tree). The observations on the number of trees affected/ha and the number of nuts affected/affected trees were counted on the day before wrapping the coconut trunk (pre census) and after at an interval of 2, 3,6,12 and 18 month period. Further the cost of wrapping Zinc sheets and polythene sheets were also worked out. The associated rodent pests in coconut orchards werenon burrowing ones, viz., *R. rattus* and *F. palmarum* which usually climb the trees and establish their colony on the crown. B. *bengalensis*, a burrowing species cause damage in coconut nurseries. Both the treatments like wrapping/ banding with zinc sheets as well as polythene sheets proved were equally effective in preventing rodent damage. Cost of these preventive treatments indicated that the zinc sheets are relatively costly (Rs. 6000/ha) compared to polythene sheets (Rs. 2000/ha) and the viability of polythene sheets were 42% against zinc sheets which is 100% at the end of 18 months (Table 33).

Table 33: Details of cost/materials for estimating C: B Ratio for polythene wrappers and zinc sheets for the management of rodents in coconut (2012-13)

SN	Parameters	Values
1	No. of trees / ha	100
2	Zinc sheets required / tree	3 Sq. ft.
3	Zinc sheets required / ha	300 Sq. ft.
4	Cost of sheets required / ha	300 x 15 = Rs. 4500/- (@ 15 Sq. ft)
5	Instillation charge	Rs. 1500/-
6	Total cost	Rs. 6000/-
7	Polythene sheets required / tree	3. Sq.ft.
8	Polythene sheets required / ha	300 Sq.ft.
9	Cost of sheets required / ha	300 x 2.50 = Rs. 750/- (@ 2.50 Sq. ft)
10	Instillation charge	1250/-
11	Total cost	2000/-
12	Total amount gained due to treatments	551 x Rs. 5 = Rs. 2755

4. EVALUATION OF VARIOUS TRAPS FOR CAPTURING VARIED SIZED RODENTS

Studies were conducted in the rodent control unit laboratory at GKVK campus. The released *R. rattus* and *M. musculus* in a free room were trapped by employing all the different types of traps such as snap trap, glue trap, wonder trap, box trap and modified snap traps. The laboratory trials indicated that for capturing medium sized rats *(R. rattus*), wonder traps proved superior (89.20%) followed by snap traps (81.74%), modified snap trap (80.77%), box trap (67.94%). However for small rodents like, *M. musculus*, box trap was found superior with 76.38% trapping followed by glue trap (74.99%) and the rest were least effective with 38-43% success. However, in order to balance trapping of varied sized rodent pests, itis effective to employ wonder traps to trap medium / big sized rats, while glue trap were effective against small *Mus* species and box traps to give equal opportunity for both big and small rodents to get trapped (Table 34).

Table 34 : Evaluation of various types of traps for capturing varied sized rodents during 2013-14 to 2014-15.

Sl. No	Trap types	2013-14 Rodents trapped (%)		2014-15 Rodents trapped (%)		Mean of two years	
		Rr	***Mm***	***Rr***	***Mm***	***Rr***	***Mm***
1	Snap trap	85.71	44.44	77.78	33.33	81.74	38.88
2	Glue trap	25.00	83.33	50.00	66.66	37.50	74.99
3	Wonder trap	87.50	44.40	90.91	30.00	89.20	37.20
4	Box trap	66.66	77.77	69.23	75.00	67.94	76.38
5	Modified snap trap	84.61	50.00	76.93	36.37	80.77	43.18

5. INDIGENOUS TECHNICAL KNOWLEDGE (ITK) IN RODENT PESTS MANAGEMENT

Table 35: Indigenous Technical Knowledge (ITK) in rodent management (data generated from farmers)

Sl. No.	Places practiced	Method followed
1	Tagachaguppe, Magadi	(i)Mechanical method by using stone slab; (ii) Sowing of 3-4 rows of Sorghum all along the border of groundnut field, while ground nut sowing
2	Gulbarga	Use of Glyricidia leaves along with rice
3	Chamarajanagar	Wooden traps and bamboo traps.
4	Dharwad district	Rodent management in rice: Short hairs are incorporated in the vada and kept in the rodent burrow for feeding, after eating, the hair create problem in the stomach of rodent Farmer feels the presence of snake reduce the rodent incidence.
5	North Canara /South Canara	Roasted groundnut mixed with jaggary and cement is used to kill the rats. The mixture is kept in the burrow. After consuming, the cement get solidified like concrete and affect the digestive system of the rats which ultimately leads to their death
6	North Canara& Southern	Chapathi made up of wheat flour mixed with jaggary and cement
7	Bangalore / Kolar district	Jatropa seeds (1/2 kg) powder is boiled in 2-3 ltr of water & Filtered decoction is taken and boiled again with 1kg of sorghum grain. Than these seeds are spread over field wherever there is rodent menance. After eating the cooked sorghum seeds the rats will die instantly
8	Bangalore rural district	Farmers using lanet in preparation of baits in place of Zinc Phosphide and fully cooked parboiled paddy as bait materials

TEACHING

The staff of AINP on Vertebrate Pest Management (Rodent Control) offered a UG course, CPT 404 (0+5) Non Insect Pests and Management, a Hands on Training/Experimental course to final year B.Sc. (Agri.) students during II semester: November 2014 to April 2015, where in students were practically exposed to rodent and other vertebrate Pests including Birds in addition to mites and invertebrate pests.

PARTICIPATION IN SEMINARS/SYMPOSIA/CONFERENCES/TRAININGS

Dr. V. Shivayya and Dr. Mohan I. Naik attended the ZREP meeting of Eastern Dry Zone of UAS, Bangalore during 11th, 12th and 13th March 2013 and presented progress of research.

Dr. V. Shivayya and Dr. Mohan I. Naik attended the ZREP meeting of Eastern Dry Zone of UAS, Bangalore during 19th ,20th and 21st February 2014 and presented progress of research**.**

Naik, M.I participated in 10th National symposium on soil Biology and Ecology, held at UAS, Bangalore, 19th to 21st February, 2014 and presented research Paper on Rodent management in Ragi, *Eleusinecoracana* (Gaertn.) ecosystem and Studies on Food preference of Lesser Bandicoot rat, *Bandicota bengalensis* (Gray) to evolve best bait for its Management.

Dr. G. Govinda Raj, Dr. V. Shivayya and Dr. Mohan I Naik, attended the Annual Entomology Technical meeting /workshop at KVK, Chamarajanagara, Mysore from Feb 11-14, 2015.

Dr. G. Govinda Raj attended the Brain storming session on Vertebrates & launch meeting of AINP on Vertebrate Pest Management at NASE complex, IARI, New Delhi on 21st February 2015.

PUBLICATIONS

Naik, M.I., Shivayya, V. and Siddappa Kannur, 2011, Rodent invasion to coffee plantation in Coorg district of Karnataka. *Rodent Newsletter, **35**:79.*

Naik, M.I. and Shivayya, V., 2012, Management of rodents in vegetable soybean, *Rodent News letter*, **36:**8.

Basavaraj,K., Naik, M.I., Rajashekar, B. Nayak, and Ganesha, 2012, Bio efficacy of ecofriendly insecticides against castor shoot and capsule borer, *Conognethespunctiferalis*(Lepidoptgera:Pyralidae). Paper presented in *International Conference on Plant Health Management for food security* held at Hyderabad, 28-30, Nov.2012, P.82.

Naik, M.I., Rajashekar B. Nayak, Shivayya, V. and Siddappa Kannur, 2012, Toxicity of Zinc Phosphide to rodents and their management in soybean field. Paper presented in *International Conference on Plant Health Management for food security* held at Hyderabad, 28-30, Nov.2012, p.148.

Naik, M.I., Rajashekar, B. Nayak and Shivayya, V., 2013, Food preference by Brown spiny field rat, *Mus playthrix* (Benet). *Environ. and Ecol*., **31**:21-24.

Naik, M.I., Rajashekar, B. Nayak and Shivayya, V., 2013, Food preference by Brown spiny field rat, *Mus playthrix* (Benet). *Environ. and Ecol*., 31:21-24.

Naik, M.I., Shivayya, V. and Siddappa Kannur, 2013, Bio efficacy of an eco-friendly chemical Brodifacoum (0.005% WB) against commensally Rodents. *Environ. and Ecol.*, **31**:16-20

Chakravarthy, A.K., Shivayya, V., R.S. Tripathi and Girish,A.C.2013.Porcupine: The robust rodent-2013.

Naik, M.I., Basavaraju, K., Rajashekar, B. Nayak and Shivayya, V., 2014. Rodent management in Ragi, *Eleusinecoracana* (Gaertn.) ecosystem, Paper presented at 10th National symposium on soil Biology and Ecology, held at UAS, Bangalore, 19th to 21st February, 2014.

Naik, M.I., Basavaraju, K., Rajashekar, B. Nayak and Shivayya, V., 2014. Studies on Food preference of Lesser Bandicoot rat, *Bandicoota bengalensis* (Gray) to evolve best bait for its Management. Paper printed at 10th National symposium on soil Biology and Ecology, held at UAS, Bangalore, 19th to 21st February 2014.

Naik, M.I. Nayak, R.B., Kannur Siddappa and Shivayya, V., 2015, Efficacy of acute rodenticides for rodent management in soybean [Glacier max L. (Merrils)]. *Bioinfole*t, 12(1) : 19-23.

Naik, M.I. Nayak, R.B., Kannur Siddappa and Shivayya, V., 2015, Dynamics of rodent community in soybean-Ragi based crop lands. *Bioinfolet*, 12(1) : 19-23.

EXTENSSION ACTIVITIES

1. RPM Demonstrations and Training Programme conducted		
Sl . No	Date	Place
1	25-7-2013	Koramangala, bijwara village, Chikkaballapura District
2	2-4-2013	kartwara village, Ramanagara,District.
3	8-5-2013	Shirabgondanahalli , Ramanagara District.
4	15-5-2013	Deevali, Kumta Tq
5	16-5-2013	Urakeri, Kumta Tq
7	31-5-2013	Gajanuru, Shimoga District
8	6-2-2015	Kachagondanalli, Magadi Tq.

2. Participation in Krishimelas Attended and organized exhibition stalls covering all aspects of Rodent Pest Management to create awareness and education on rodent pests			
Sl. No	Date	Place	Beneficiaries
1	Nov., 19-21, 2015	GKVK Campus, Bangalore (UAS, Bangalore)	> 6 lakhs visitors - farmers, NGO's, enterpreueners and School children's etc
2	Feb., 05-07, 2015	Ramanagara Dist. (zilla panchayat)	> 5 thousands visitors including farmers, school children etc.,
3	March, 01-06, 2015	Shri kshethra Adi Chunchanagiri, Mandya Dist. (Adi Chunchanagiri mutt)	> 3 thousands including farmers, school children and others.

3. Guest Lectures and TV Programme on Rodent Pest Management Aspects.		
Sl. No.	Date	Activities
1	16-09-2014	Guest lecture to officials of the Department of Horticulture, at CIPM, Bangalore.
2	27-10-2014	Live Dooradharsan programme, telecasted by Chandana channel
3	03-02-2015	Trained the officials of Department of Agriculture on Rodent Pest Management aspects at CIPM, Padmanabanagar, Bangalore.

4. Extension services in University Departments / Units	
1. Farmers Training Institute	10. Dry land Research unit
2. VC's office	11. Seed Production Center
3. Food and Nutrition Unit	12. Administrative office
4. UG girls hostel	13. Animal Sciences Department
5. Agro-meteorology Unit	14. International hostel
6. Library	15. Telephone exchange unit
7. Department of Agricultural extension	16. Dean (Agri.) office
8. PG hostel	17. PG Students research plots,
9. Examination Center	18. Biotechnology Dept.
10. Agricultural Engineering Dept	20. Dept of Agricultural Marketing

University of Agricultural Sciences, Bangalore
Actual expenditure for the FY 2012-13 to 2014-15
(ICAR Share only)

(Rs. in lakhs)

Head/ Year	2012-13	2013-14	2014-15	Total
Pay & Allowances	75.80	50.61	52.96	**179.37**
T.A.	0.30	0.60	0.59	**1.49**
Rec. Contingencies	0.90	1.79	1.69	**4.38**
NRC	0.00	0.00	0.00	**0.00**
Total	**77.00**	**53.00**	**55.24**	**185.24**

ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY, A.P.R.R.I. AND R.A.R.S., MARUTERU

PART I: GENERAL INFORMATION

1. Name of the centre	ANGR University, APRRI & RARS, Maruteru
2. Sanction no.	Proc. No.Res.1/93015/77 Dated 20.06.1883
3. Date of start	23.09.1985
4. Date of Termination	Network Project of continued nature
5. Report period	2012-13 to 2014-15
6. Scientist In charge (PI)	Dr N. Srinivasa Rao

7. Staff Position

Name	Designation	Data of joining	Date of leaving
Dr Ch V. Narsimha Rao	Sr Scientist	12.11.2010	25.11.2014
Dr N. Srinivasa Rao	Sr Scientist I/c	30.05.2015	Contd
Mrs D. Sudha Rani	Scientist	22.10.2010	08.10.2013
Ms B. Anusha	Scientist	24.02.2014	Contd
Mr. B. Ram babu	Tech Assistant	08.01.2015	Contd
(i) Smt.S.Mary Jnana Kumari	Agricultural Extension Officers	12.08.2011	Contd
(ii) Sri.V.Trimurthulu	(2)	21.11.2011	Contd
Vacant	Lab Assistant (1)	-	-

PART II: WORKS ALLOTTED

RM 1. Surveillance of rodent pests in predominant cropping system (Groundnut-Sugarcane and (ii) Plantation crops)

RM 2. Monitoring of rodent abundance and damage in different agro climatic zones (Krishna and High altitude Zone)

RM 3.Evaluation of botanicals against rodent pests for antifeedant /deterrent/ attractant effects

RM 4.Evaluation of chemical compounds for toxic and antifertility properties for data generation on Indian rodents

RM 5. Development of rodent management technologies under storage conditions

RM 6. Bio-ecology of major rodent species(Mus booduga/ *Bandicota bengalensis*)

RM7.Development of integrated rodent management modules in predominant crops/cropping systems

RM 8. Social engineering activity on rodent pest management as participatory adaptive research in adopted villages

RM 9. Studies on predatory potential of barn owls and its utilization for bio-control of rodent pests

LOCATION SPECIFIC PROGRAMME

(a): Evaluation of CTBS

(b): Development of rodent forewarning systems in Godawari Delta region of AP (by correlating climate data vis a vis population dynamics of last 15 years)

(c): Field Evaluation of Difencoum and flocoumafen in rice and coconut as sponsored trial from BASF India Pvt Ltd.

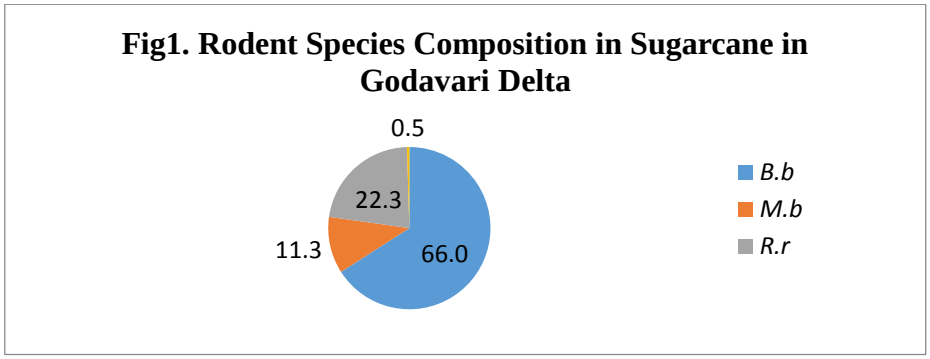
PART III: WORKS DONE

1. SURVEILLANCE OF PEST RODENTS IN PREDOMINANT CROPPING SYSTEMS

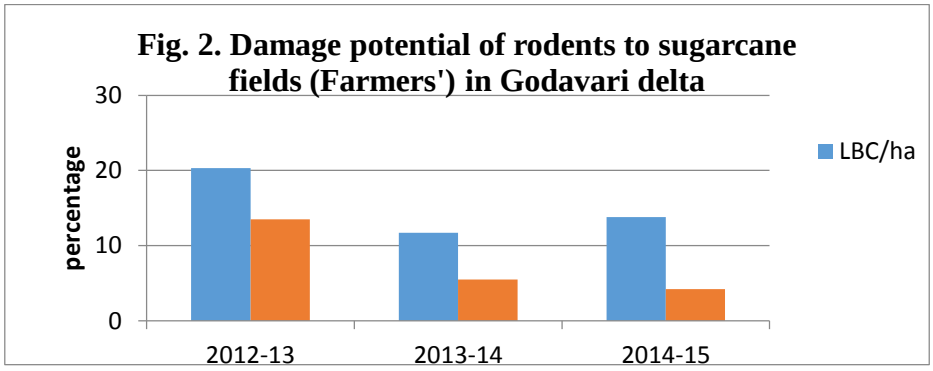
Rodent pest surveillance was carried out in sugarcane, maize, cocoa and coconut crops from farmers' fields consecutively for the three years.

1.1. Sugarcane

Among the rodent species present in sugarcane fields, *B. bengalensis* (66.0%) is the major followed by *R. rattus* (22.0%) *M. booduga* (11.3%). Very rare incidence of *M. meltada* (0.5%) was noticed in sugarcane fields in the region (Fig.1).

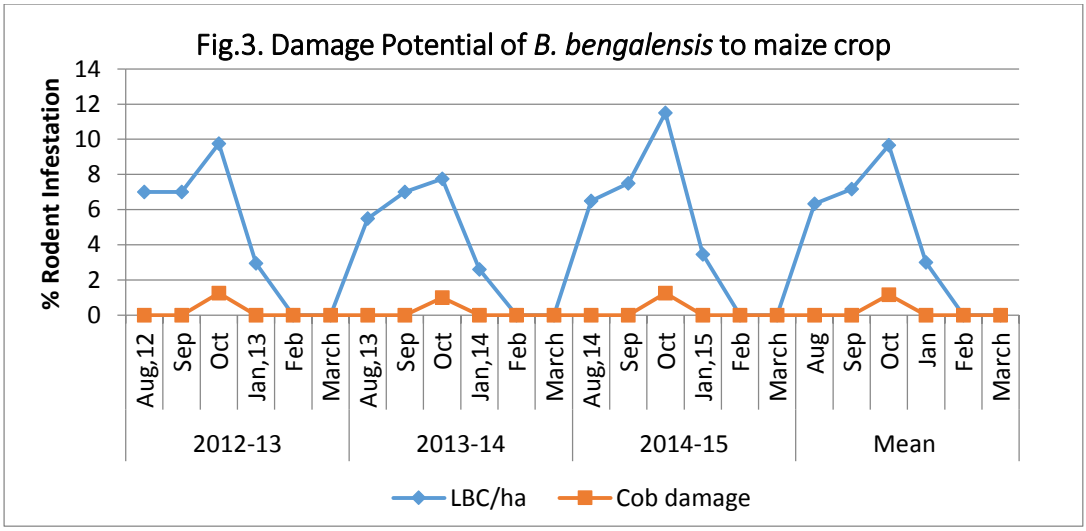


Rodent infestation was found high in farmers' sugarcane fields in Godavari delta with 21.0 LBC/ha and 13.0% cane damage during 2012-13 and it was receded in subsequent years with 12-14 LBC/ha and 4-6% cane damage as a result of rodent control campaigns organized (Fig.2)



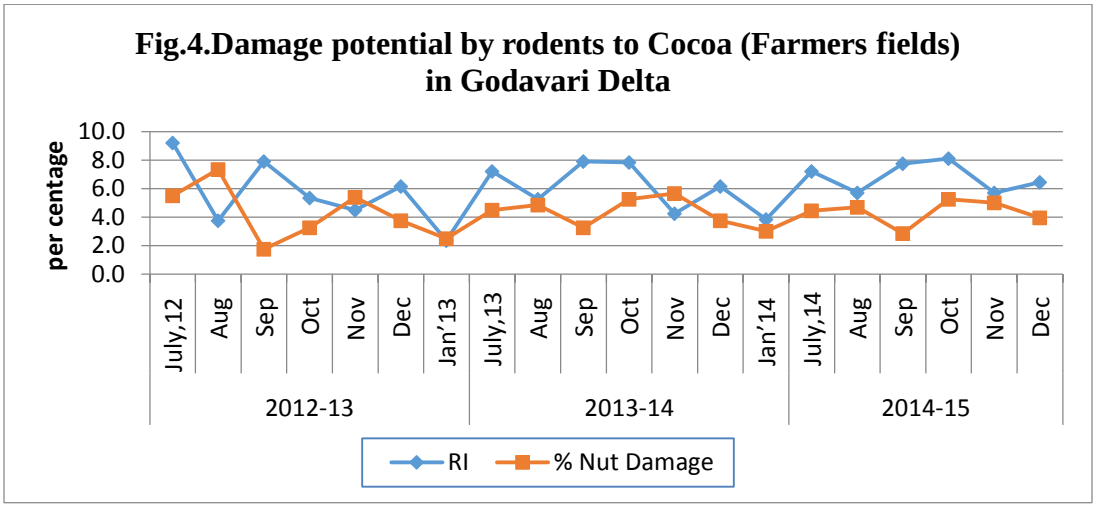
1.2.Maize

The main species infesting maize crop was found as *Bandicota bengalensis*. The mean live burrow count is more during the October month i.e., 9.66 which varied from 7.75 – 11.5 during the 3 years. Though the rodent infestation is found in maize, the cob damage is very low or negligible. In crop growth period, cob damage by rodents was noticed during October (mean 1.16) which is also very low or negligible (Fig. 3)

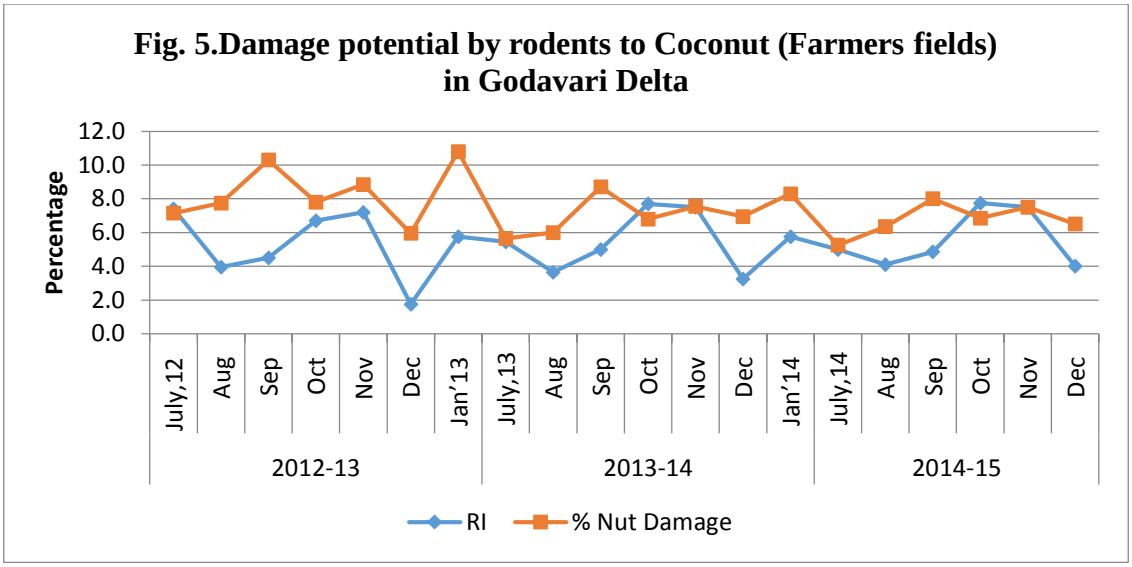


1.3. Plantation Crops (Cocoa and Coconut)

Cocoa is an export oriented high value crop grown as intercrop in coconut orchards in deltaic regions in Godavari belt. Rodents are one of the major biological constraints in cultivation of cocoa and coconut as well. Rodent infestation was recorded during the major season i.e. kharif (June to Jan) for the three years. The data was recorded from two orchards, one at ARS, Ambajipet and another at Sakinetipalli (Farmer's field). Rate of rodent infestation (RI) and pod damage varied throughout the season and no relation (positive or negative) between RI and pod damage are noticed. Peak rodent infestation rates are noticed during July (7.2 to 9.2), September (7.8 to 7.9) and December (6.2 to 6.5) months in all the three years (Fig.4). Rodent infestation is very low during the months of January and November.

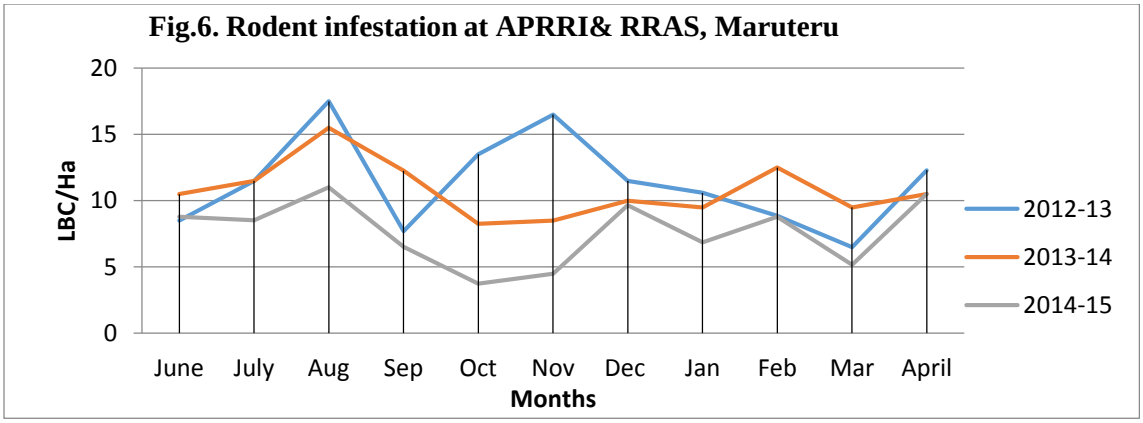


Rate of rodent infestation and damage to nuts were also assessed from the same gardens. Rodent infestation is fluctuated throughout the season and highest rate of infestation is noticed in the month of October and November in all the three years. Damage to nuts was more in 2012-13 and it was reduced subsequently. In generals peaks in nut damage were notice in the months of September and January during all the three years (Fig.5)



2. MONITORING OF RODENT ABUNDANCE AND DAMAGE IN SELECTED AGRO-CLIMATIC ZONES OF THE REGION

From the monitoring surveys conducted in Krishna-Godavari Zone during the three years, rodent species, *B. bengalensis* is found predominant (85.0%) followed by *Mus booduga* (10.0%). During Kharif seasons, the population is slowly build up and reached a peak during the month of August during all the three years of study (11-17.5 LBC/ha). Later there was a fall in the population which might be due to the community campaigns taken up by the farmers in survey areas. While in *rabi* seasons, high rodent infestation is noticed during the months of February and April. It is understood from the graph that the rodent infestation is high during the periods when the crop is entering into the reproductive phase (at about maximum tillering to PI stage). (Fig.6)



The mean breeding parameters recorded from the animal samples collected at APRRI, Maruteru for the three years are depicted in fig.7. High percent pregnant females were found during October when the crop is in reproductive phase. Percent feeding females i.e. females with litter are found more during December, January, March and February moths. The mean no. of embryos is also more during these months. And, these pregnant and feeding females are present throughout year indicating the presence of overlapping and mixed populations in the region.

The productivity is relatively higher in kharif over *rabi* season. Population growth estimate computed from breeding parameters indicated that the *B. bengalensis* infesting paddy could breed @ 2.46 to 2.69 times in kharif and 1.13 to 1.67 times in *rabi* seasons, with

the seasonal productivity of 23.17 to 26.52 in kharif and 13.51 to 19.80 in *rabi* seasons. Reproductive rate and annual productivities evolved from the breeding parameters revealed that animal can produce about 40 to 43 litter per year.

Fig.7. Breeding parmeters of *B. bengalensis* at APRRI, Maruteru

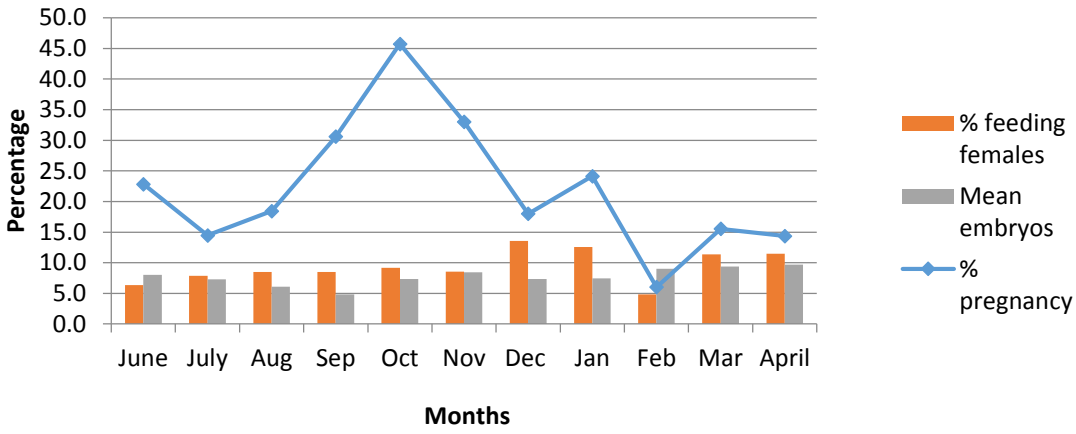


Table 1. Population growth parameters of *B. bengalensis* at Maruteru during 2012-13, 2013-14 and 2014-15

S.No.	Population growth parameter	Values					
		Kharif 2012	***Rabi 2012-13***	***Kharif 2013***	***Rabi 2013-14***	***Kharif 2014***	***Rabi 2014-15***
1	Reproductive rate F*	2.69	1.13	2.58	1.85	2.46	1.67
2	Average litter / female	8.96	11.96	8.58	10.62	9.42	11.86
3	Productivity per season (F x Avg. litter/ female)	26.52	13.51	22.13	19.64	23.17	19.80
	Productivity per year	40.03		41.77		42.97	

*F= P (t/v), where P- Prevalence of pregnancy (Avg. % Pregnant / season)
t- Time period of samples in days, V- time of gestation.

3. EVALUATION OF BOTANICALS AGAINST RODENT PESTS FOR ANTI-FEEDENT/ DETERRENT/ ATTRACTANT EFFECTS

Experiments on botanicals were carried out from 2008-09 to 2011-12 and concluded during bi-annual group Meeting held at Guwahati, Assam.

4. EVALUATION OF CHEMICAL COMPOUNDS FOR TOXIC AND ANTI-FERTILITY PROPERTIES FOR DATA GENERATION ON INDIAN RODENTS.

Not conducted

5. DEVELOPMENT OF RODENT MANAGEMENT TECHNOLOGIES UNDER STORAGE CONDITIONS

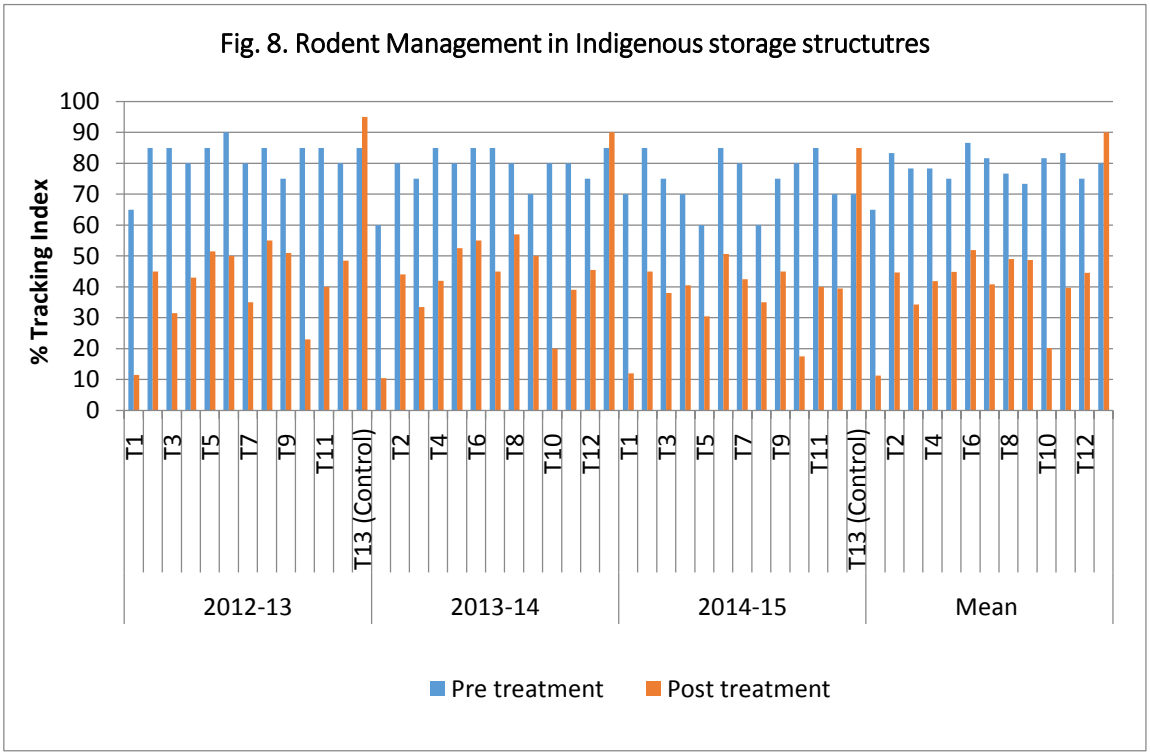
The post-harvest losses due to rodents also a major constraint in achieving the national food security. Indirect losses are 10 times more than actual losses cause by direct feeding. Further the losses are more in indigenous storage structures which are more often non-rodent poof. Experiments were carried out develop rodent management techniques in these structures. Tracking tiles were placed to measure tracking index (rodent infestation) before and after treatments in experimental sites i.e. A P seeds Godown at Maruteru and small indigenous storage structures in Kotalaparru village. The following treatment modules are tested.

Table 2. Efficacy of various treatments against rodents in storage structures

Treatments	**Modules applied**	**% Control Success**			
		2012-13	**2013-14**	**2014-15**	**Mean**
T1	Bromodiolone cake poisoning +Sherman traps	84.0	85.0	82.8	83.9
T2	Bromodiolone cake poisoning +Wonder traps	52.8	54.8	47.0	51.5
T3	Bromodiolone cake poisoning +Glue/sticky traps	67.0	65.0	53.3	61.7
T4	Bromodiolone poison baiting +Sherman traps	52.2	50.2	42.1	48.1
T5	Bromodiolone poison baiting +Wonder traps	46.0	48.0	49.1	47.7
T6	Bromodiolone poison baiting + Glue/sticky traps	50.6	58.6	40.3	49.8
T7	Zinc phosphide poison baiting + Sherman traps	61.6	60.6	46.8	56.3
T8	Zinc phosphide poison baiting + Wonder traps	42.4	40.4	41.6	41.4
T9	Zinc phosphide baiting + Glue/sticky traps	39.5	40.5	40.0	40.0
T10	Aluminium phosphide tablets + Sherman traps	76.0	78.0	78.1	77.3
T11	Aluminium phosphide tablets + Wonder traps	58.2	59.2	52.9	56.7
T12	Aluminium phosphide tablets + Glue/sticky traps	46.0	50.0	43.5	46.5
T13	Control	-	-	-	-

The mean pre-treatment tracking index varied between 73.33- 86.66 % during the years and it was reduced to 11.33 - 51.9 in various treatments (T1 – T12) (table2). Whereas in control, where no rodent control operations were taken, the post treatment tracking index increased from 80 to 90 per cent. Among the treatments tested, Bromodiolone cake and Sherman traps (T1) has resulted in lowest post-treatment tracking index. (Fig 8.).

Based on the pre and post tracking indices, the control success was estimated in comparison with control treatment. Among the treatments, T1 (Bromodiolone cake poisoning +Sherman traps) has recorded a mean % control success of 83.9 followed by T10 (Aluminium phosphide tablets + Sherman traps) with 77.3 and T3 (Bromodiolone cake poisoning +Glue/sticky traps) with 61.7 per cent rodent control success over the control treatment (Table 2).



6. BIO-ECOLOGY OF MAJOR RODENT SPECIES (*MUS BOODUGA*)

Experiments were carried out during 2010-11 to 2012-13 and concluded during the workshop held at Assam.

7. DEVELOPMENT OF INTEGRATED RODENT MANAGEMENT MODULES IN PREDOMINANT CROPS/CROPPING SYSTEMS

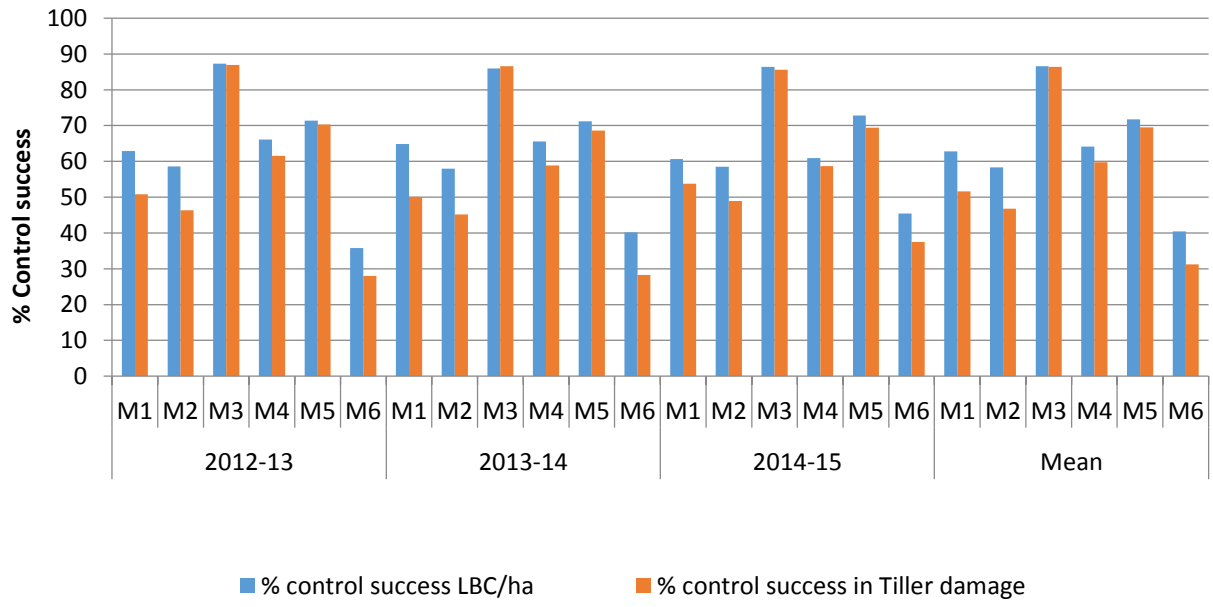
Rice: Various modules comprising rodent management practices alone or in integration considering the crop stage were evaluated consecutively for three years against rodents in irrigated rice. The module details are furnished below.

Module	**Rodent management operations**		
	Tillering stage	**Panicle Initiation stage**	**Harvest stage**
M1	Bromodiolone poison baiting	Zinc phosphide poison baiting	Bromodiolone poison baiting
M2	Bromodiolone poison baiting	Bromodiolone poison baiting	Bromodiolone poison baiting
M3	Burrow smoking (once in a week)	Bromodiolone poison baiting & Burrow smoking (once in a week)	Burrow smoking (once in a week)

M4	Burrow fumigation with ALP	Bromodiolone poison baiting	Burrow fumigation with ALP
M5	Trapping (1 month after transplanting for every 2 alternate days) Repellent spraying (once)	Burrow smoking Repellent spraying (once)	Trapping (1 month before harvest for every 2 alternate days)
M6	Farmers practice (phorate granules application, bromodiolone baiting with incorrect dosages and live catch of rodents through catchers engaged)		
M7	Control		

Among all the modules tested, the module M3 (Cultural Practices + Bromodiolone burrow baiting + burrow smoking) was found to be the most promising module and achieved a mean percent control success of 86.57 in reducing live burrows and 86.37 in reducing the tiller damage (Fig. 9) for all the three years. Burrow smoking found to be a crucial component/ practice in this module for achieving higher rate of success. The next best treatment was M5 with 72 % and 69% mean control success in reducing live burrows and tiller damage, respectively. All the modules recorded superior performance in controlling the rodents over control. Farmers practices like application of phorate granules and application of inadequate doses of bromadiolone baiting and live catching has performed inferior among all the modules.

Fig. 9. Efficacy of rodent management modules in irrigated rice



Sugarcane: In order to control the rodent damage and to disseminate the technology, community rodent control campaigns were organized in adopted villages (during 2012-13 & 2013-14 at Abbirajupalem and 2014-15 at Doddipatla) using bromadiolone 0.005%. These campaigns has resulted in reduction of LBC from 24 to 8 in 2012-13, 20.5 to 4.5 in 2013-14 and 22.6 to 5.2 in 2014.15. The per cent control success in reduction of LBC was 69.7, 77.2

and 77.0, respectively. Campaign villages recorded a control success of 60.5 to 85.9 % in reducing the cane damage due to rodents over the non-campaign villages (Table 3).

Table 3. Efficacy of bromodiolone 0.005% poison bait in reduction of rodent infestation in sugarcane crop (Farmer Fields)

Year	Field	Mean LBC/ha			Mean per cent cane damage/ha		
		Pre Treatment	Post treatment	% control success	Pre treatment	Post treatment	% control success
2012-13	Treated	24	8	**69.7**	19	3	**85.9**
	Control	29	32		24	27	
2013-14	Treated	20.5	4.5	**77.2**	12.5	3.5	**62.6**
	Control	19.0	17.5		14.0	10.5	
2014-15	Treated	22.6	5.2	**77.0**	15.7	6.2	**60.5**
	Control	19.2	17.4		15.7	12.3	

Plantation Crops: In order to manage the rodents in cocoa-coconut intercropping, the following 5 modules are evaluated for their efficacy in three replications

M1- Cultural Practices (CC) + Bromodiolone 0.005% baiting
M2- CC + Bromodiolone burrow baiting 0.005% + burrow fumigation
M3- CC + Trapping + Ecodon
M4- CC + Bromodiolone burrow baiting 0.005% + Trapping
M5- farmer's practice
M6- Control (No treatment)

Table 4. Efficacy of certain treatments against rodents in cocoa and coconut

Module	Cocoa				Coconut			
	% Control Success				% Control Success			
	2012-13	2013-14	2014-15	Mean	2012-13	2013-14	2014-15	Mean
M1	57.17	65.67	67.53	63.46	65.05	62.20	58.82	62.02
M2	51.16	63.62	62.50	59.09	68.38	64.78	54.54	62.00
M3	66.26	60.13	61.48	62.62	55.37	56.75	54.16	55.43
M4	**74.98**	**81.15**	**75.00**	**77.04**	**72.63**	**75.0**	**72.22**	**73.28**
M5	61.16	56.93	51.72	56.60	53.12	58.96	55.55	55.88

The percent rodent control success in terms of reduction in nut damage (difference between pre and post treatment) in different modules over control is presented in the table 4. All the modules recorded higher control success over the control which is varied from 56.6to 77.04 % in cocoa and 55.43 to 73.28 % coconut over the three years. Among the modules tested, M4 has recorded highest mean control success both in cocoa (77.04) and coconut (73.25) followed by M1 (CC+bromadiolone 0.005% baiting) with mean control success of 63.46 % in cocoa and 62.0 % in coconut.

In cocoa, the mean pre-treatment pod damage varied between 12.6 to 18.6 % during the years and it was reduced to 3.1 to 6.5 in various treatments (M1-M5). Whereas in control, where no rodent control operations were taken, the post treatment nut damage increased 18.6 to 20.3 per cent. Among the modules tested, M4 (CC+ Bromadiolone 0.005% baiting+ Trapping) has resulted in lowest post-treatment pod damage (Fig.10).

In coconut, among the modules tested, M4 (CC+ Bromadiolone 0.005% baiting+ Trapping) has showed superior performance over the other in controlling the rodent incidence. The mean pre-treatment % nut damage varied from 8.3 to 11.0 among the treatments. The % nut damage was reduced to 2.6 to 5.3 in treatments (M1 to M5), whereas it was increased from 9.3 to 11.5% in control (fig. 11)

Fig. 10 Efficacy of treatments in containing cocoa pod damage by rodents (farmers fields)

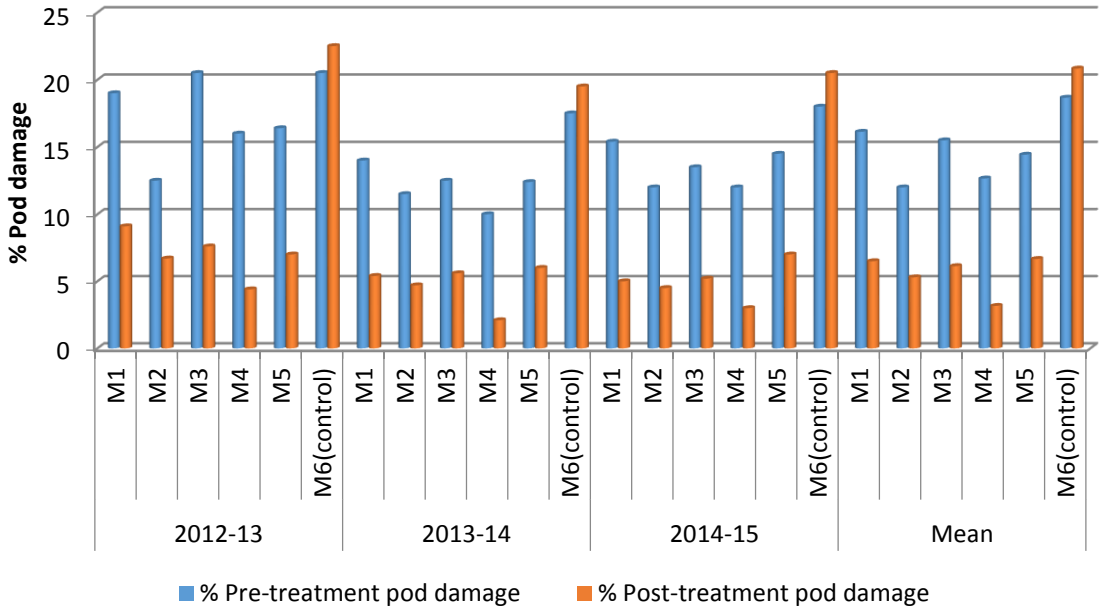
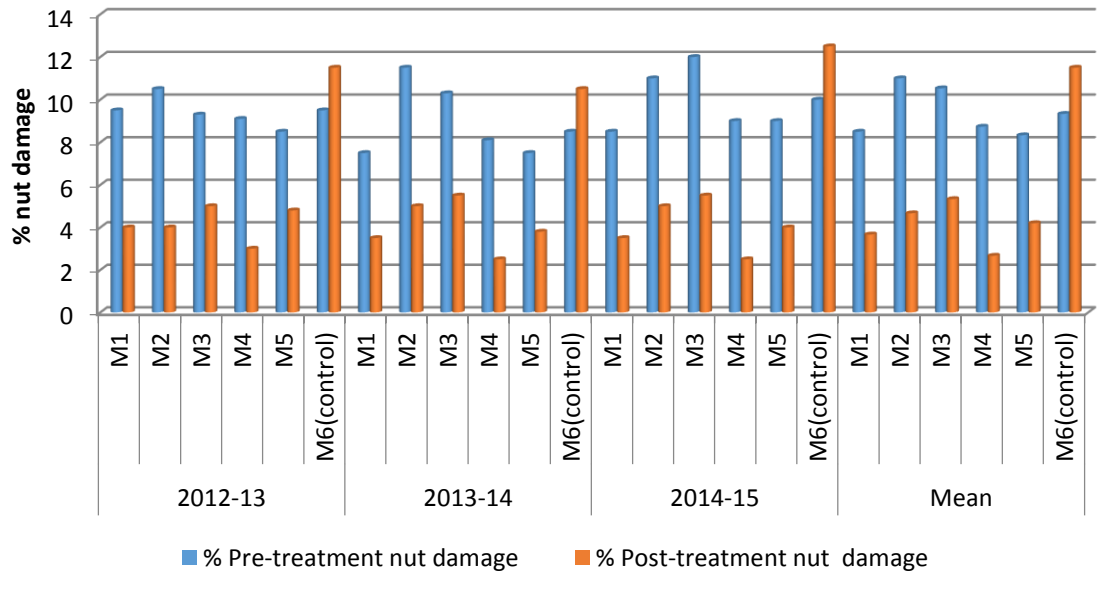


Fig. 11. Efficacy of treatments in containing coconut damage by rodents (farmers fields)



8. SOCIAL ENGINEERING ACTIVITY ON RODENT PEST MANAGEMENT AS PARTICIPATORY ADOPTIVE RESEARCH IN ADOPTED VILLAGES

Rodents are being migratory crop pests; community approach is required in controlling them. Social engineering is practiced to achieve technology adoption by motivating the farmers' participation. Three villages were selected with the help of Department of Agriculture/ KVK, Undi for project implementation.

1st village- knowledge will be provided and campaign will be organized on community basis with complete technical support from the project
2nd village- only knowledge will be provided
3rd village- control

KAP analysis will be conducted before and after campaign in all the three villages. Based on the KAP, the motivational media (Demonstrations and interactions) was selected to create the awareness among the farmers. Rodent control success will be calculated in all the three villages after organizing the community rodent control campaign using rodenticide poison baiting (packeting and pocketing) using bromadiolone 0.005% CB.

In all selected villages, majority of the farmers fall under the category of secondary adopters, accordingly, motivational media (demonstrations and interactions) were arranged to create awareness among the farmers (Table 5).

Table 5. Knowledge (K) Attitude (A) and Practice (P) levels of the farmer in selected villages

Parameter	Village	2012-13		2013-14		2014-15	
		Kharif	***Rabi***	***Kharif***	***Rabi***	***Kharif***	***Rabi***
Knowledge (K) Score	Kottalparru (1)	68.0	70.3	75.2	74.5	78.4	76.4
	Lankala Koderu (2)	60.3	65.2	61.4	67.2	60.7	65.2
	Pippara (3)	59.0	59.5	58.5	60.5	59.2	61.3
Attitude (A) Score	Kottalparru (1)	84.5	82.6	80.4	80.3	81.5	82.3
	Lankala Koderu (2)	79.5	79.0	76.5	80.0	75.7	77.4
	Pippara (3)	70.5	73.3	59.5	70.3	58.4	60.5
Practice (P) Score	Kottalparru (1)	68.0	70.4	70.5	72.4	72.8	74.5
	Lankala Koderu (2)	60.0	65.5	61.5	70.5	62.9	66.4
	Pippara (3)	59.5	61.0	56.5	62.0	55.6	63.5

Table 6. Impact of rodent control social engineering in protecting the crop against rodents

Name of the village	**K.Parru**	**L.Koderu**	**Pippara**	**K.Parru**	**L.Koderu**	**Pippara**
Experimental area in hectares	100	80	60	100	80	60
Year	**Kharif 2012**			**Rabi 2012-13**		
LBC/ha (a)Pre-treatment	35.0 4.3	36.7 7.3	37.7 23.0	36.3 7.8	35.2 12.8	36.3 34.2

LBC/ha (b)Post-treatment						
% Rodent control success	**79.97**	**67.57**	**--**	**77.2**	**61.5**	**--**
% tiller damage (a) Pre treatment	21.13 5.53	19.33 7.8	21.13 23.06	15.41 5.8	16.76 8.96	20.5 24.0
% tiller damage (b) Post treatment						
% Rodent control success	**76.2**	**63.3**	**--**	**74.97**	**55.0**	**--**
Year	**Kharif 2013**			**Rabi 2013-14**		
LBC/ha (a)Pre-treatment	33.0 5.3	34.7 8.3	35.7 22.0	34.3 8.5	33.2 16.9	33.3 32.4
LBC/ha (b)Post-treatment						
% Rodent control success	**74.03**	**62.67**	**--**	**75.8**	**58.5**	**--**
% tiller damage (a) Pre treatment	25.23 4.53	22.03 9.83	25.33 26.36	16.41 6.0	19.76 9.20	18.5 17.0
% tiller damage (b) Post treatment						
% Rodent control success	**83.66**	**57.16**	**--**	**78.25**	**57.5**	**--**
Year	**Kharif 2014**			**Rabi 2014-15**		
LBC/ha (a)Pre-treatment	37.0 6.2	34.7 8.9	35.7 23.0	36.2 7.9	32.7 8.7	34.6 33.4
LBC/ha (b)Post-treatment						
% Rodent control success	**83.24**	**74.35**	--	**78.17**	**73.40**	--
% tiller damage (a) Pre treatment	26.82 5.56	24.32 8.64	26.66 25.12	20.50 5.40	18.64 6.4	19.82 18.80
% tiller damage (b) Post treatment						
% Rodent control success	**79.26**	**64.47**	--	**73.65**	**65.66**	--

In village 1 (Kotalaparru), the rodent control success ranged between 74.03 to 83.24 per cent in terms of reducing the live rodent burrows and it was 76.2 to 83.66 per cent in terms of reducing the tiller damage. In village 2 (L. Koderu) where Social engineering is practices partially, the rodent control success was low compared to village 1. In control village (village 3-Pippara), rodents caused extensive damage (Table 6). This indicating that the rodent pests can be managed very effectively in farmers fields through social engineering.

LOCATION SPECIFIC PROGRAMMES

(a): Evaluation of CTBS

Experiments were carried out during 2008 to 2010 and concluded during the workshop held at Assam

(b): Development of rodent forewarning systems in Godavari Delta region of AP (by correlating climate data vis a vis population dynamics of last 15 years.

Under progress

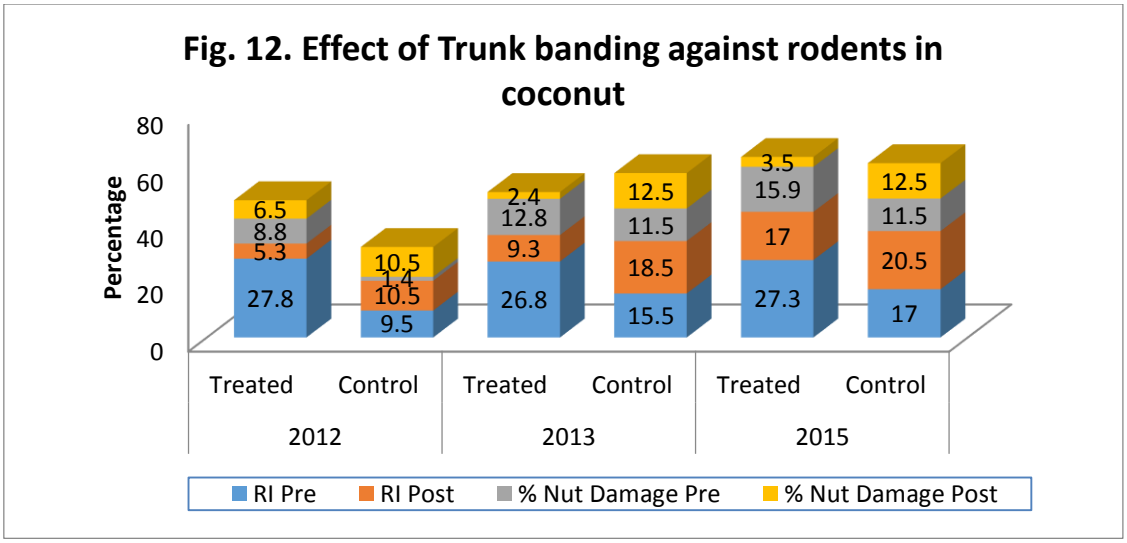
(C): Evaluation of polythene trunk banding for management of rodents in Coconut

Trunk banding with metallic sheet/ erecting metallic guards around trunk is an age old preventive technique to arrest the passage of rodent pests on to the crown. Trunk banding with polythene sheet is an economically viable and easily adoptable preventive technique, was evaluated consecutively for three years for its efficiency. Pre-treatment rodent infestation rates (%) were ranged from 9.5 to 27.8 among the treatments and it was reduced in the trees where polythene trunk banding is practiced. The control success in reduction of infestation rates was 71.07 to 82.8 in banded trees over the un-banded trees over the years (Table.7)

Table 7. Effect of polythene trunk banding against rodent pests in coconut

Year	Coconut orchard	Rate of Infestation (RI)			% Nut damage		
		Pre treatment	Post treatment	% control success	Pre treatment	Post treatment	% control success
2012-13	Treated	27.8	5.3	**82.8**	8.8	1.4	**90.7**
	Control	9.5	10.5		6.5	10.5	
2013-14	Treated	26.8	9.3	**71.07**	12.8	2.4	**82.7**
	Control	15.5	18.5		11.5	12.5	
2014-15	Treated	27.3	6.8	**75.19**	15.9	3.5	**78.2**
	Control	17.0	20.5		11.5	12.5	

The % nut damage varied from 8.8 to 15.9 among the trees before trunk banding and trunk banding has resulted in decrease in nut damage to 1.4 to 3.5 %. Trunk banding with polythene sheet has resulted in control success of 78.2 to 90.7 % in reducing the nut damage caused by rodents (Fig.12)



(D): Field Evaluation of Difenacoum and Flocoumafen in rice and coconut as sponsored trial from BASF India Pvt Ltd.

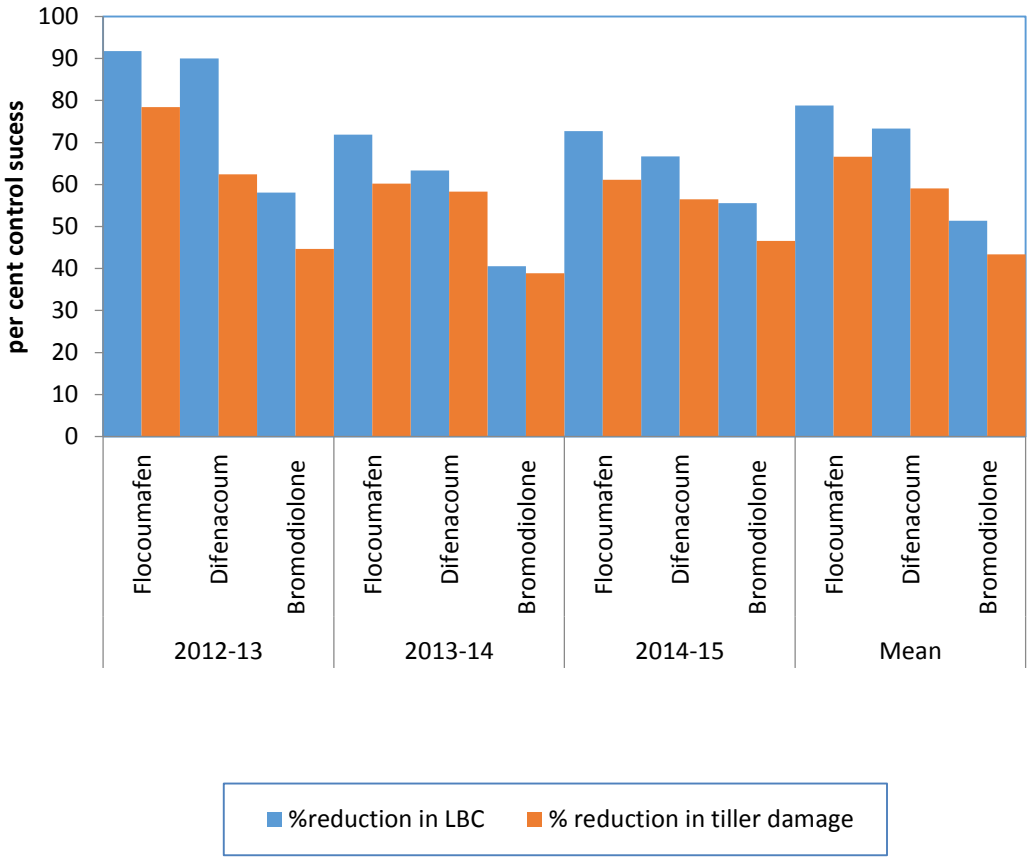
Two second generation anticoagulant rodenticides i.e. Flocoumafen 0.005%RB @8.0g/ burrow and Difenacoum 0.005%RB@ 8.0g/burrow were evaluated in comparison with existing rodenticide, Bromadiolone 0.005% @10.0g bait packet/ burrow for their field efficacy against lesser bandicoot, *B. bengalensis* in irrigated paddy ecosystem. Efficacy of rodenticides is represented in terms of reduction in live burrows and tiller damage.

Table. 8. Field efficacy of two new anticoagulant rodenticides in rice

Year	Treatment	Rodent Infestation (LBC/ ha)		% control success	% Tiller damage		% control success
		Pre treat	Post treat		Pre treat	Post treat	
2012-13	Flocoumafen	15.5	1.5	91.72	10.5	2.5	78.40
	Difenacoum	11.2	1.3	90.02	8.0	3.2	62.44
	Bromodiolone	12.4	5.2	58.06	11.2	6.2	44.64
	Control	12.5	14.5	-	10.8	11.5	-
2013-14	Flocoumafen	24.5	6.5	71.87	23.5	8.5	60.21
	Difenacoum	21.2	7.3	63.35	19.0	7.2	58.32
	Bromodiolone	20.5	11.5	40.53	22.5	12.5	38.88
	Control	16.5	15.5	-	16.0	14.5	-
2014-15	Flocoumafen	22	6	72.72	38.60	15.00	61.13
	Difenacoum	15	5	66.66	33.10	14.41	56.46
	Bromodiolone	18	8	55.55	46.80	25.00	46.58
	Control	19	18		47.72	6.84	-

Pre-treatment live burrows count was varied from 11.2 to 24.5 among the treatments and it was reduced to greater extent in fields treated with rodenticides (1.3 to 8). Among the rodenticides tested, Flocoumafen 0.005% showed highest per cent control success in reducing live burrows (78.7) and tiller damage in (66.6) followed by Difenacoum 0.005% with 73.0 and 59.0, respectively. Both the newer rodenticides has showed super performance over the existing Bromadiolone in reducing the rodent infestation in rice (Fig. 13)

Fig. 13 Efficacy of new rodenticide against *B. bengalensis* in irrigated paddy



OTHER ADDITIONAL EXPERIMENTS CONDUCTED

(i) Population dynamics of *Rattus rattus* in Poultry farms: Rodents are one of the major production constrains in poultry. Rodents cause damage to eggs, chicks, poultry feed and poultry structures besides transmitting several diseases to birds. *Rattus rattus* was the major species present inside the poultry sheds with rare incidence of burrows of *B. bengalensis & B. indica* on the ground. Bandicoots are majorly seen outside around the sheds. Experiments were conducted to study the population dynamics of *R. rattus* and its management in poultry. The pregnant females were trapped throughout the season, peak breeding activity was seen from August to September and February (Fig. 14). *R. rattus* could breed @3.67 and 2.62 times per season with the seasonal productivity of 33.20 and 19.6 young ones per female during kharif and rabi, respectively. The annual productivity was 53.1 young ones per female (Table 9).

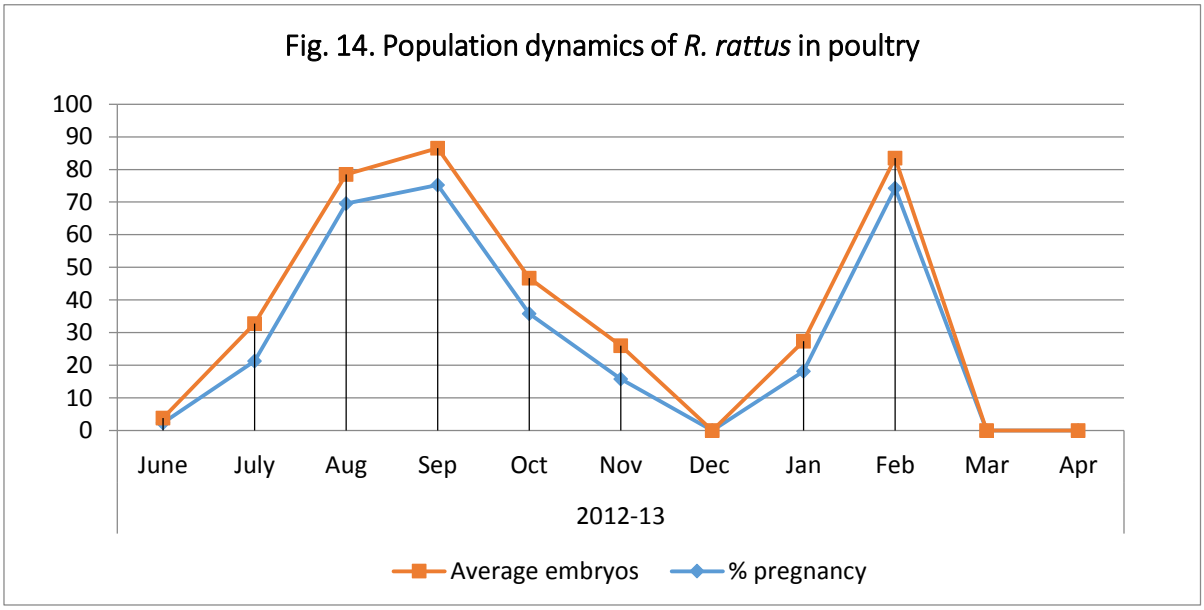
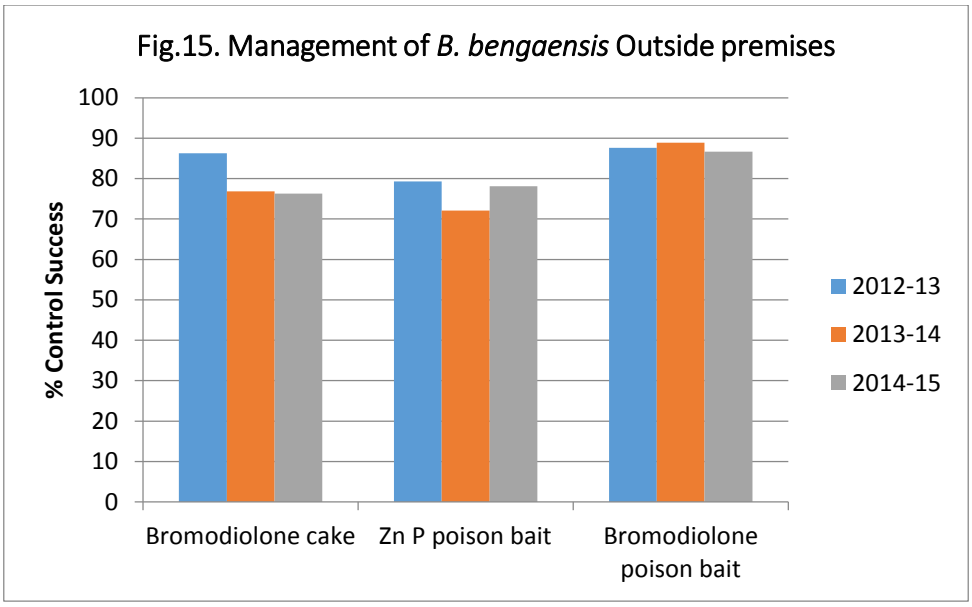


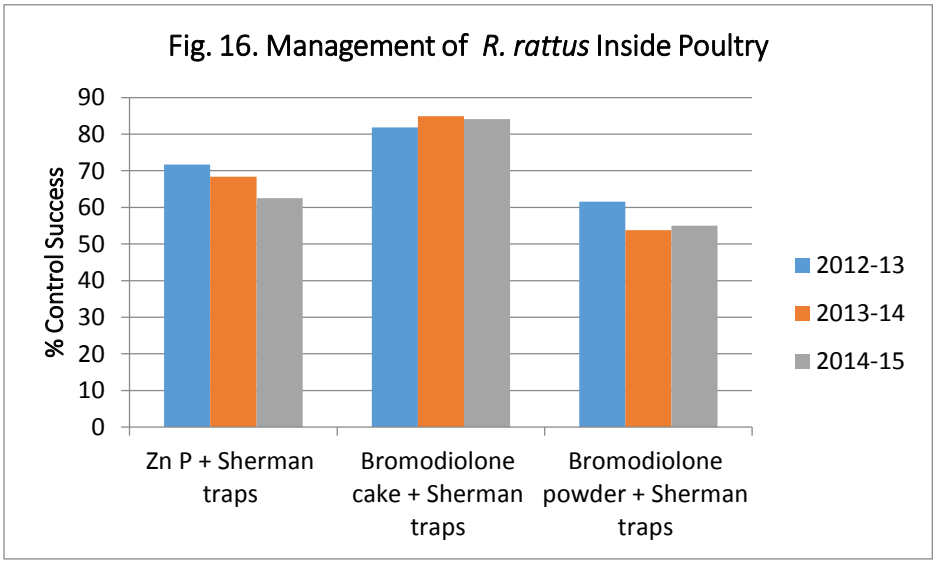
Table 9. Annual Productivity of *Rattus rattus* in poultry farms

S. No	Population growth parameter	Values	
		Kharif 12	**Rabi 12-13**
1	Reproductive rate F*	3.67	2.62
2	Average litter / female	9.04	7.6
3	Productivity per season (F x Avg. litter/ female)	33.20	19.9
4.	Annual productivity	53.1	

Studies on management of rodents outside the premises of poultry units indicated that bromodiolone loose poison bait was effective in controlling *B. bengalensis* with a mean per cent control success of 87.72 during all the years (2012-13,2013-14,2014-15) followed by Bromodiolone cake and Zn P poison bait with a mean percent control success of 79.80 & 76.5 respectively. (Fig. 15)



Management of rodents inside the poultry units indicated that bromodiolone cake with sherman traps was effective in controlling the *R. rattus* with a mean percent control success of 83.62 (Fig. 16) during all the years (2012-13, 2013-14, 2014 -15).



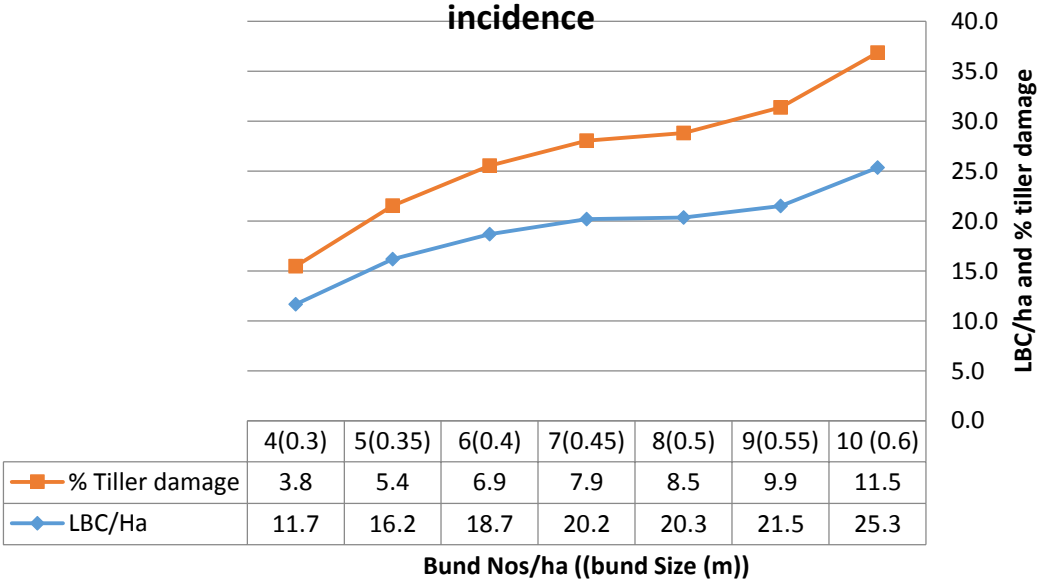
ii. Preliminary studies on optimization of bund size relating to rodent pest management: Field bunds are the primary source of habitation for the burrowing rodents, especially lesser bandicoots in irrigated paddy. Rodents cause damage to the crops in their home range after establishing on the field bunds, which can be seen as isolated damage patches in paddy. Studies were conducted to assess the impact of number and size of field bunds on rodent incidence and their infestation in the crop. Data was recorded from the unit bund size. Rodent incidence (LBC/ha) and infestation (% tiller damage is low if the bund number and bund size is low during all the years.

Table 10. Impact of bund number and size on rodent incidence

Treatment Specifications			2012-13		2013-14		2014-15	
	Bund Nos./ha	*size (m)	LBC /ha	% Tiller damage	LBC/ha	% Tiller damage	LBC/ha	% Tiller damage
T1	10 (4+6)	0.60	25.5	12.3	25.5	12.3	25.0	10.0
T2	9 (4+5)	0.55	22.0	10.3	22.0	10.3	20.5	9.0
T3	8 (4+4)	0.50	21.5	8.7	21.5	8.7	18.0	8.0
T4	7 (4+3)	0.45	20.5	7.5	20.5	7.5	19.5	8.6
T5	6 (4+2)	0.40	20.0	7.3	20.0	7.3	16.0	6.0
T6	5 (4+1)	0.35	16.5	5.3	16.5	5.3	15.5	5.5
T7	4 (4 sides of 1 ha)	0.30	12.5	3.6	12.5	3.6	10.0	4.2
Unit bund size is uniform to all treatments *i.e.*, 250 x 40 x 0.3m								

Treatment (T7) has recorded minimum number of live rodent burrows (10.0 to 12.5/ ha) and lower tiller damage (3.6 to 4.2) over the other treatments. Treatment 1 (T1) has recorded highest number of live burrows (25.0 to 25.5/ ha) and higher tiller damage (10.0 to 12.3%) as the bund number and size are more in this treatment. The rodent incidence as well as tiller damage is increased with increase in bund number and size (Fig. 17 and Table 10)

Fig. 17 Impact of bund size and number on rodent incidence



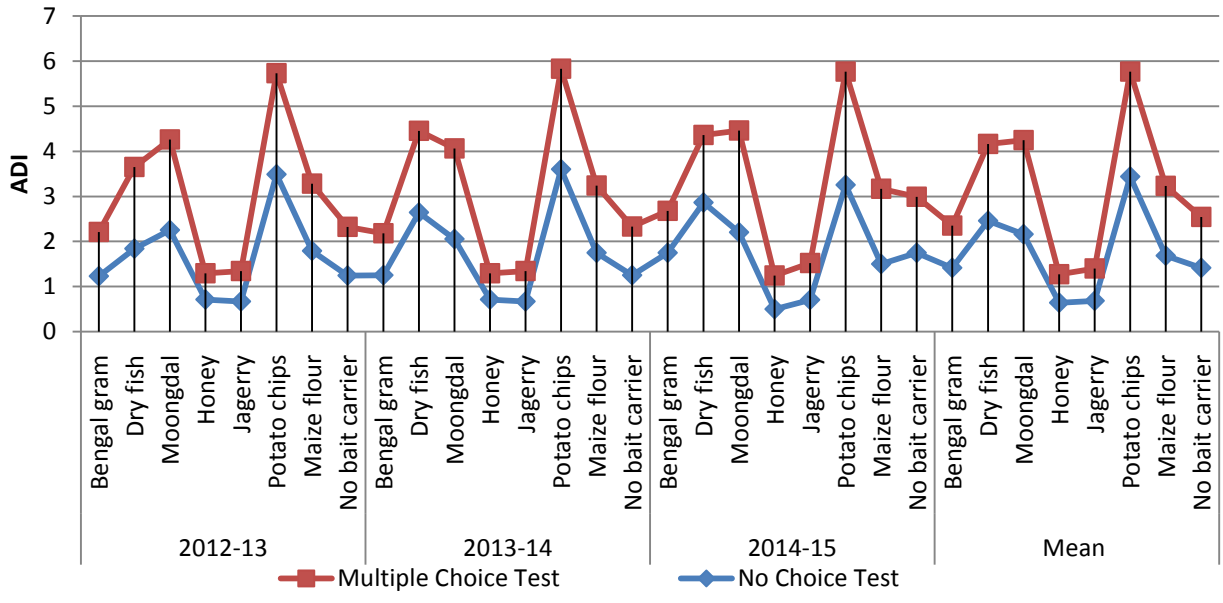
iii. Evaluation of bait carrier for *B. bengalensis* in paddy: Success of rodent control is influenced by the amount of the poison bait taken by the target species. Most often rodents escape the mortality with intake of sub lethal doses, when the bait is not palatable. Hence the palatability (taste) of bait plays a crucial role in achieving desirable rodent control. Different bait carriers were evaluated for improving the poison bait uptake by *B. bengalensis*. The following bait additives tested with the following combinations (Table 11).

Table 11. Evaluation of bait carriers on poison bait intake by *B. bengalensis*

Treatments	Bait Ingredients			
	Poison (rodenticide)	Broken rice	Bait carrier	Oil
T1	2parts	94 parts	2parts (Bengal gram)	2parts
T2	2parts	94 parts	2parts (dry fish)	2parts
T3	2parts	94 parts	2parts (Moong dal)	2parts
T4	2parts	94 parts	2parts (Honey)	2parts
T5	2parts	94 parts	2parts (Sugar)	2parts
T6	2parts	94 parts	2parts (Potato chips)	2parts
T7	2parts	96parts	0	2parts

Among all the treatments tested during 3 years, highest bait consumption of 3.34g /day mean ADI (no-choice) and 2.33g/day mean ADI (multi- choice) was recorded, where Potato chips are added to the bait material. The next best treatments are Dry fish and Moong dal bait additives in multi as well as no-choice feeding tests (Fig. 18).

Fig. 18 Efficacy of various bait carriers against *B.bengalensis*



EXTENSION ACTIVITIES

I. REFRESHER TRAINING ORGANIZED

S.no	Training programme	Date	Venue	Organized by
1.	National training (7 days) programme on Rodent Pest Management	20-26th , February, 2013	APRRI & RARS, Maruteru	APRRI & RARS, Maruteru & NIPHM, Hyderabad.

II. RADIO/T.V. PROGRAMMES

S. No	Name of the faculty	Name of Radio/T.V.Programmes	Date of broadcast	Place
1	Smt. D.Sudha Rani Scientist (Ento.)	Kobbarilo yelukala Yajamanyam	08.03.2012	AIR,Vijayawada
2	Smt.D. Sudha Rani Scientist (Ento.)	Rasayanethara --------- yelukala nivarana	07.03.2012	E-TV Annadatha @ 6.30AM
3	Smt. D.Sudha Rani Scientist (Ento.)	Yelukala nivaranalo ----- --- aardika pramukyatha	08.03.2012	E-TV Annadatha @ 6.30AM
4	Dr.Ch.V.Narasimha Rao Senior Scientist (Ento)	Rodent management in summer	14.05.2012	Doordarshan (Saptagiri) at 6.30 PM.
5	Dr.Ch.V.Narasimha Rao Senior Scientist (Ento)	Rodent Pest Management before kharif	19.06.2012	Doordarshan (Saptagiri) at 6.30 PM.
6	Dr.Ch.VNarasimha Rao Senior Scientist (Ento)	Rodent Pest Management in paddy	18.09.2012	AIR, Vijayawada
7	Dr.Ch.V.Narasimha Rao Senior Scientist (Ento)	Rodent Pest Management in paddy	28.07.2012	FM Vishnu Radio, Bhimavaram
8	Dr.Ch.V.Narasimha Rao Senior Scientist (Ento)	Rodent Pest Management in Paddy	04.10.2012	**TV 5-Phone in live @5.30PM**
9	D. Sudharani	Rodent Pest Management	20.03.2013	Doordarshan (Saptagiri) at 6.30 PM.
10	Dr.Ch.V.Narasimha Rao Senior Scientist (Ento)	Rodent Pest Management in rabi paddy	25.04.2013	Doordarshan (Saptagiri) at 6.30 PM.
11	Dr.Ch.V.Narasimha Rao Senior Scientist (Ento)	Vesavilo yelukala yajamanyam	13.05.2013	Doordarshan (Saptagiri) at 6.30 PM.
12	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento)	Vesavilo yelukala yajamanyam	27.06.2013	E-TV Annadatha @ 6.30AM
13	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento)	Varilo yelukala yajamanayam	30.06.2013	E-TV Annadatha @ 6.30AM
14	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento)	Internode borer management in sugarcane	15.08.2013	E-TV Annadatha @ 6.30AM
15	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento)	Scale insect management in sugarcane	17.08.2013	E-TV Annadatha @ 6.30AM
16	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento)	Root grub management in sugarcane	19.08.2013	E-TV Annadatha @ 6.30AM

17	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento)	IPM in redgram	27.09.2013	E-TV Annadatha @ 6.30AM
18	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento)	Rodent Pest Management in paddy	21.09.2013	E-TV Annadatha @ 6.30AM
19	Scientists of RARS, Maruteru	Crop seminar on Paddy	31.03.2014	DD Saptagiri 6 PM
20	Dr. M. Nanda Kishore Scientist (Ento)	Vesavilo yelukala yajamanyam	14.06.2014	E-TV Annadatha
22	Ms. B. Anusha Scientist (Ento)	Rodent Pest Management in Coconut & Cocoa	13.11.2014	DD Saptagiri
23	Ms. B. Anusha Scientist (Ento)	Rodent Pest Management in Coconut & Cocoa	25.11.2014	Express -TV
24	Dr. M. Nanda kishore Scientist (Ento)	Varilo Elukala Samagra yajamanyam suchanalu	2-3-2015	AIR, Vijayawada

III. GUEST LECTURES DELIVERED

S.no	Name of the faculty	Topic	Date	Place
1	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in Summer	30.5.2012	ADA Office, Bhimavaram
2	Dr. Ch. V. Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy	4.6.2012	NIPHM,Hyd
3	Dr. Ch. V. Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy	18.6.2012	DAATTC, Eluru
4	Dr. Ch. V. Narasimha Rao, Sr Scientist (Ento)	Training on conduct of rodent campaign to AOs & ADAs	7.7.2012	JDA Office, Eluru
5	Dr. Ch. V. Narasimha Rao, Sr Scientist (Ento)	Rodent pest management and safety measures on use of plant protection equipment	13.7.2012	KVK, Undi
6	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management' to the AEOs in view of the Rodent control campaign in the District on 25.7.2012.	17.7.2012	JDA Office, Eluru
7	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy	28.7.2012	KVK, Undi
8	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy	4.8.2012	DAATTC, Eluru

10	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy, cocnut	7.8.2012	KVK, Undi (SAC meeting)
11	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy	21,22.8.2012	Kakinada (ZREAC)
12	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy	3.9.2012	AMC, Palakollu
13	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in Coconut and cocoa	11.9.2012	HRS, Ambajipeta
14	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy	4.8.2012	DAATTC, Eluru
15	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-FFS	11.10.2012	ADA office, Narsapuram
16	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Training programme	17.10.2012	ADA Office, Amalapuram
17	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Training programme	1.11.2012	Amalapuram, org.by KVK, Kalavacharla
18	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	IPM in sugarcane including rodent pest management	5.11.2012	Andhra Sugars, Tanuku
19	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Training programme	9.11.2012	Dept of Agrl. Yanam
20	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Training programme	22.11.2012	ADA Office, Narsapuram
21	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy and coconut- Training programme	30.11.2012	Kadiapulanka org.by KVK, Kalavacharla
22	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Training programme	19.12.2012	ADA, Tanuku
23	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-T& V programme	21.12.2012	JDA Office, Kakinada
24	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Training programme	24.12.2012	ADA, Tanuku
25	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Integrated Rodent Pest management	11.2.2013	YSR HU, Venkataramanna-gudem

26	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Training programme	12.2.2013	ADA, Tanuku
27	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management' to the farmers in view of the Rodent control campaign in the District	18.2.2013	JDA office, Kakinada
28	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-RCY	22.4.2013	Duvva
29	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-RCY	25.4.2013	D.Muppavaram
30	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-RCY	2.5.2013	Doddipatla
31	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Rythu sdassu	12.5.2013	Ravulapalem
32	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Rythu sdassu	14.5.2013	Gokavaram
33	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in paddy-Rythu sdassu	16.5.2013	Penugonda
34	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in Cocoa	27.6.2013	NASA, Tuni org.by HRS, Ambajipeta
35	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Sugarcane Production and protection technologies	21.10.2013	Valluru. Org.by Enadu
36	Dr.Ch.V.Narasimha Rao, Sr Scientist (Ento)	Rodent pest management in Cocoa	22.11.2013	Annavaram
37	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento) Ms. B. Anusha Scientist (Ento)	Rodent pest management in Cocoa	23.6.2014	HRS, Ambajipeta
38	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ento)	Rodent Pest Management to Veterinary Officials	22-24, July 14	NIBSM, Raipur
39	Dr.Ch.V.Narasimha Rao,Senior Scientist (Ento)	Rodent pest management in paddy and coconut	31.07.2014	Kothapeta
41	Dr.Ch.V.Narasimha Rao,Senior Scientist (Ento)	Rodent pest management in paddy and coconut	02.08.2014	Ganti

42	Dr.Ch.V.Narasimha Rao,Senior Scientist (Ento)	Production and Protection technologies in Rice	16.08.2014	Razole
43	Dr.Ch.V.Narasimha Rao,Senior Scientist (Ento)	Production and Protection technologies in different crops (Polam Pilusthundi)	12.08.2014 13.08.2014 26.08.2014 27.08.2014	Kovvur Agril Sub- division
44	Ms. B. Anusha Scientist (Ento)	Production and Protection technologies in different crops (Polam Pilusthundi)	12.08.2014 13.08.2014 19.08.2014 20.08.2014	Rajahmundry Rural Agril Sub-division
45	Dr.Ch.V.Narasimha Rao,Senior Scientist (Ento)	Rodent Pest Management (Rodent Control Campaign)	24.09.2014	Penugonda, Penumantra, Atthili, Iragavaram
46	Dr. M. Nanda Kishore Scientist (Ento)	Rodent pest management in rice and sugarcane	28.10.2014	Kollur, KCP Sugars

3. Scientists of AINP on Rodent control, Maruteru were involved in mass rodent campaign at East and West Godavari districts on 25th July, 2012 and 26th February, 2013.

4. Nineteen diagnostic surveys were made during June- December 2013 in Narsapuram, Razole, Mogalturu, Tanuku, Nidadavole, Bhimavaram, Undi, Kotalaarru, Lankalakoderu, Bantumilli and Jangareddigudem villages.

5. During 2014-15 the scientists made more than 20 diagnostic visits to villages; K R Puram, Rampachodavaram, Ganti, Palakollu, Bhimavaram, Tanuku, Koyyalagudem, Chinthalapudii, Unguturu, Rajahmundry, Visakhapatnam, Vizianagaram, Srikakulam, Maruteru Agril. Sub divisions, Tadepalligudem & Bhimadole Agril. Sub divisions and Raazole

IV. AWARDS AND HONOURS

6. **Dr. Ch.V.Narasimha Rao,** Senior Scientist (Ent) received **STAI Silver Medal** for BEST PAPER PRESENTATION on 'Innovative research on efficient use and conservation of fuel in sugar industry' at 10th Convention held at STAI, Pune, Maharashtra(November, 2011).
7. **Smt. D. Sudha Rani, Scientist (Entomology)** has been awarded **Young Scientist Award** for her research contributions for 2011 by Rotary Club, Maruteru.

PUBLICATIONS

(i) Research articles

Sudharani D., Ch.V.Narasimha Rao, Y. Suryanarayna, M. Bharathalakshmi, 2013. Evaluation of various Integrated Rodent Management modules in irrigated rice ecosystem. *Rodent news Letter* 37 (1-2): 9-10

Sudharani D. and Narasimha Rao Ch. V. 2014. Evaluation of Botanicals against Rodent Pests in irrigated Paddy. *International Journal of Applied Biology and Pharmaceutical Technology*. 5 (3): 163-167.

Nanda Kishore M and B Anusha. 2014. Rodent management in Indigenous storage structures. *Rodent Newsletter* 38(1-4):10

Sudharani D., Narasimha Rao Ch. V., Suryanarayana Y and Bharathalakshmi M. 2015. Studies on Efficacy of Bait Carriers in Enhancing Bait preferences among the Lesser Bandicoot, *Bandicota bengalensis*. *European Journal of Biomedical and Pharmaceutical Sciences*. 2 (3): 163-167.

(ii) Tech bulletins/ Manuals

8. A multi-colour page technical bulletin (in English) on 'Rodent Pest problems and their Management in Rice' was published by the Rodent Control Scientists and was released by the Project Coordinator, AINP on Rodent Control on 26.2.2013.
9. A Training manual on Rodent Pest Management' was published by the Rodent Control Scientists and was released by the Associate Director of Research and JDA, W.G. District on 20.2.2013.

(iii) Popular Articles

1	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent),	*Vepatho 300 purugula atakattu*	Sakhsi –Padi panta	3.5.2012
2.	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent),	*Purugu chinnade.. kani nastam peddadi*	Sakhsi –Padi panta	6.6.2012
3	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent),	*Ivee pantala rasanni peelchestai*	Sakhsi –Padi panta	7.6.2012
4	Dr.Ch.V. Narasimha Rao, Senior Scientist (Entomology)	*Yelukala nermulanaku ide adanu*	Sakshi paper	Dt 5/7/12
5	Dr.Ch.V. Narasimha Rao, Senior Scientist (Entomology)	*Balya dhasya nundi ventaduthundi (peeka purugu)*	Sakshi paper	Dt 26/7/12
6	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent)	*Veetipai avagavhana penchukovali*	Sakshi – Padipanta	Dt 4.9.2012
7	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent)	*Ivi kooda rasam peelustai*	Sakshi – Padipanta	Dt 5.9.2012

8	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent), D Sudharani,Scientist(Ent)	*Peruguthunna midathala bedada*	Enadu-Rytheraju	Dt 7.9.2012
9	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent)	*Midathalu dadichestai jagratha*	Sakshi – Padipanta	Dt 10.9.2012
10	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent)	*Chearakulo yelukala bedada*	Enadu-Rytheraju	Dt 15.9.2012
11	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent) D Sudharani,Scientist(Ent)	*Yelukalu dadi cheste matashe*	Sakshi – Padipanta	Dt 19.9.2012
12	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent) D Sudharani,Scientist(Ent)	*Cherakulo yelukala bedada-Nivarana*	Rythu Nestham monthly	September, 2012 pp: 47
13	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent) D Sudharani,Scientist(Ent)	*Vyavasayamlo midathala samasya – Nivarana*	Rythu Nestham monthly	September, 2012 pp: 48
14	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent)	*Cherakulo yelukala bedada*	Agriclinic monthly	September, 2012 pp: 24-25
15	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent) D Sudharani,Scientist(Ent)	*Yelukala Pravarthanalu-Yajamanyam*	Panchadara cheruku	Oct issue Pg:24-26
16	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent)	*Vyavasayam lo midathala samasya*	Panchadara cheruku	Oct issue Pg:21-22
17	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent), D Sudharani,Scientist(Ent)	*Cherukulo Yelukala Bedadha*	Panchadara cheruku	Oct issue Pg:11-12
18	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent)	*Yelukala Pravarthanalu-Yajamanyam*	Rythuvani	Oct issue
19	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent) D Sudharani,Scientist(Ent)	*Vyavasayam lo midathala samasya*	Agriclinic	Oct issue Pg:11-12
20	Dr.Ch.V. Narasimha Rao, Senior Scientist (Ent)	*Varipyruku Yelukala Thegulla Bedadha*	Eenadu-Rytheraju	Dt 19.10.2012

21	Dr.Ch.V.Narasimha Rao, SS (Ent) & D. Sudharani	*Elukala pani pattandila'*	Sakshi – Padi panta	dated 25.11.2012
22	Dr.Ch.V.Narasimha Rao, SS (Ent) & D. Sudharani	*Varilo Elukala yajamanyam*	Vari samachara lekha	Oct-Nov, 2012 issue pp: 4
23	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Ippatinunde melkovali*	Sakshi – padipanta	9.1.2013
24	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Cherakulo sasyarakshana*	Sakshi – padipanta	15.3.2013
25	Dr.Ch.V.Narasimha Rao, SS (Ent) & D. Sudharani	*Yelukala nivaranaku vesavi anukulam*	Vari samachara lekha	April-June, 2013 issue pp: 1
26	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Rasanni peelustai jagratha*	Sakshi – padipanta	11.4.2013
27	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Ee nallulatho jara bhadram*	Sakshi – padipanta	12.4.2013
28	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Cherakulo pindinalli nivarana*	Enadu rytheraju	25.4.2013
29	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Cheraku thotallo lakkapurugula bedada*	Enadu rytheraju	28.4.2013
30	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Kobbari chetlapai yelukala nivarana*	Enadu rytheraju	4.5.2013
31	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Vesavilo yelukala nivarana*	Enadu rytheraju	10.5.2013
32	Dr.Ch.V.Narasimha Rao, SS (Ent)	*Ee nallulatho jagratha*	Sakshi – padipanta	17.5.2013
33	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Mushika nirmoolana samoohikanga chepattali*	Enadu – *Mukhakukhi*	3.6.2013
34	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Yelukala bharatham pattandila*	Sakshi – padipanta	6.6.2013
35	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Midathala dandu vasthondi*	Sakshi – padipanta	14.6.2013
36	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Pilla puruge kada anukovaddu*	Sakshi – padipanta	25.6.2013
37	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*300 purugula aata kattistai*	Sakshi – padipanta	1.8.2013
38	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Vanalu paduthunte dadi chestai*	Sakshi – padipanta	23.8.2013
39	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Varilo Elukala nivarana*	Eenadu- Rytheraju	22.9.2013

40	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Elukalu dadi cheyyochhu*	Sakshi – padipanta	25.9.2013
41	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Varilo yelukala samagra yajamanyam*	Annadatha monthly October, 2013	October, 2013 Pp: 10-11
42	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Yelukala pravarthananugunanga yajamanyam*	Vari samachara lekha	July-Sept, 2013 25(3):4
43	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Cherakulo pindinalli*	Eenadu- Rytheraju	22.10.2013
44	Dr.Ch.V.Narasimha Rao, Senior Scientist (Ent)	*Cherakunu kapadukondila…*	Sakshi – Padipanta	31.10.2013
45.	B.Anusha, Ch.V.N.Rao and A V Reddy	Rodent diseases and their risk to public health	Agri Gold Swarna sedyam	21-10-14
46.	B. Anusha and P V Satyanarayana	*Varilo Elukala nivarana*	Eenadu- Rytheraju	22.10.2014
47	B. Anusha and P V Satyanarayana	*Varilo Elukala nivarana*	Eenadu- Rytheraju	25.2.2015

iv. Seminars/Workshops/Training programmes attended

S. N.	Name of the faculty	Name of the training/workshop	Period	Place
1	Smt. D. Sudha Rani	Summer School on 'Vertebrate Pest Management'	May,17 to June,6.2012	NIPHM, Hyderabad
2	Dr.Ch. V. Narasimha Rao,	All India Group Meeting on Rodent Control	Jan. 22-24, 2013	AAU, Guwahati
3	Dr. Ch. V. Narasimha Rao	2 day workshop on 'Current Scenario of Rodenticides and their future Outlook'	Feb. 21-22, 2014	DOR, Hyderabad
4.	Ms. B. Anusha	Brain Storming Session on Higher Vertebrate Pests	Feb.21.2015	NASC,New Delhi
5.	Dr. M. Nanda Kishore and Ms. B. Anusha	State Level Technical Programme	April, 27-28. 2015	ANGRAU
6.	Ms. B. Anusha	2nd Foundation Course for Faculty of Agricultural Universities	May 1- 31, 2015	NAARM, Hyderabad

Acharya N.G. Ranga Agricultural University, Maruteru

Actual expenditure for the FY 2012-13 to 2014-15
(ICAR Share only)

(Rs. in lakhs)

Head/ Year	**2012-13**	**2013-14**	**2014-15**	**Total**
Pay & Allowances	17.42	14.77	15.66	**47.85**
T.A.	0.22	0.21	0.28	**0.71**
Rec. Contingencies	0.82	0.64	3.00	**4.46**
NRC	0.00	000	2.23	**2.23**
Total	**18.46**	**15.62**	**21.17**	**55.25**

Assam Agricultural University, Jorhat

PART I: GENERAL INFORMATION

1. Name of the centre	Assam Agricultural University, Jorhat
2. Sanction no.	No.3-DARE,01-10-2001
3. Date of start	23-03-2001
4. Date of Termination	Network Project of continued nature
5. Report period	2012-13 to 2014-15
6. Scientist In charge (PI)	Dr R K Borah, Sr. Scientist

7. Staff Position

Name	Designation	Grade	Data of joining	Date of leaving
1. Dr. R K Borah	Senior Scientist	Scientist	15-06-2009	Continuing
2..Dr B C Dutta	Principal Scientist	Scientist	26-08-2014	-do-
3. Mrs. Renu Bordoloi	Steno Typist	III Grade	01-06-2001	-do-
4.Mr B N Saikia	Field Assistant	-do-	01-06-2011	-do-
5..Mr D Gogoi	Field Assistant	-do-	03-05-2010	-do-
5.Mr.P K Phukan	Field Assistant	-do-	15-07-2011	31-03-2015
6.Mr.T Dutta	Field Assistant	-do-	24-02-2006	31-12-2014

PART II: Works Allotted

RM 1. Surveillance of rodent pests in predominant cropping system (rice –pulse-toria)

RM 2. Monitoring of rodent abundance and damage in different agro climatic zones of Assam (Lower Brahmaputra Valley Zone of Assam)

RM 3.Evaluation of botanicals against rodent pests for antifeedant /deterrent/ attractant effects

RM 4.Evaluation of chemical compounds for toxic and antifertility properties for data generation on Indian rodents

RM 5. Development of rodent management technologies under storage conditions

RM 6. Bio-ecology of major rodent species(*Bandicota bengalensis*)

RM7.Development of integrated rodent management modules in predominant crops/cropping systems

RM 8. Social engineering activity on rodent pest management as participatory adaptive research in adopted villages

RM 9. Studies on predatory potential of barn owls and its utilization for bio-control of rodent pests

LOCATION SPECIFIC PROGRAMME

(a): Collection, cataloguing and evaluation of local traps
(b): Seasonal incidence of *Dremnmys lokriah* in plantation crop
(c): Rodent management in poultry farms

1. SURVEILLANCE OF RODENT PESTS IN PREDOMINANT CROPPING SYSTEM (RICE –PULSE-TORIA)

1.1. Incidence of rodents in rice-toria cropping system

Surveillance of rodent pests in rice –toria cropping system was carried out at Jamuguri (Hatichung mouza) under Central Brahmaputra Valley Zone (CBVZ) of Assam in 2013-14 and 2014-15.

Table 1. Incidence of rodents in rice-toria cropping system during 2013-15

Crop	Crop stage	LBC/ha	TI	Damage (%)
Rice	Maximum tillering	12.60	4.80	4.62
	Milky	32.20	8.62	12.86
	Ripening	40.80	11.86	16.80
Toria	Vegetative	-	-	-
	Flowering	22.60	6.28	4.60
	Pod formation	26.20	10.66	8.42

The data (Table 1) reveals that live burrow count (LBC), trap index and rodent damage (%) recorded at different crop growth stages increased with the advancement of the crop growth .The LBC /ha (12.60) was recorded at maximum tillering stage of the rice crop which increased to LBC/ha of 32.20 and 40.80 at milky and ripening stage, respectively. At the maximum tillering stage the trap index recorded was 4.80.The highest trap index (11.86) was recorded at ripening stage of rice. Maximum cut tillers damage (16.80%) was recorded at ripening stage of the rice followed by milky stage (12.86%) and maximum tillering stage (4.62%).

Maximum trapping of rodents was recorded at the ripening stage of rice whereas no trapping was recorded in the vegetative stage of toria. It has been recorded that toria crop grown after rice faced maximum rodent damage at the silica/pod formation stage .The vegetative stage of the crop recorded no rodent damage (Table 1).

The trapping data in rice-toria cropping system revealed predominance of *Bandicota bengalensis* followed by *Mus* spp. and *Rattus* spp.

1.2. Incidence of rodents in rice-pulse cropping system

The data presented in Table 2 reveal that LBC/ha, trap index and per cent damage increased with the advancement of growth of rice crop. The LBC /ha (10.60) was recorded at maximum tillering stage of the rice crop which increased to LBC/ha of 26.40 and 38.20 at milky and ripening stage, respectively. Trap index was low at the maximum tillering stage (3.62).The highest trap index (11.16) was recorded at ripening stage of rice. Maximum tillers damage (14.40%) was recorded at ripening stage of the rice followed by milky stage (8.60%).No rodent activity had been recorded at the vegetative stage of the pea crop. The highest LBC/ha (16.60), trap index (6.66) and damage per cent (14.80) was recorded at pod formation stage of pea crop. The rodent incidence was more in rice as compared to pea crop. The predominant rodent species recorded were *B. bengalensis*, *Rattus* spp, *Mus* spp. and *Dremomys lokriah*

Table 2. Incidence of rodents in rice-pulse cropping system during 2013-15

Crops		Crop stage	LBC/ha	TI	Damage (%)
Rice		Maximum tillering	10.60	3.62	3.11
		Milky	26.40	8.72	8.60
		Ripening	38.20	11.16	14.4
Pea		Vegetative	-	-	-
		Flowering	8.80	2.89	4.06
		Pod formation	16.60	6.66	14.80

1.3. Incidence of rodents in pulse-toria cropping system

The rodent incidence in terms of LBC/ha (10.60) had been recorded from vegetative stage of the black gram whereas at flowering and pod formation stage, LBC/ha of 18.80 and 24.60 had been recorded in black gram. Similarly, Maximum trap index of 8.88 was recorded at pod formation stage followed by flowering stage (6.62). The data reveal from Table 3 that LBC/ha, trap index and per cent damage increased with the advancement of growth of toria. The highest LBC/ha, trap index and per cent damage were recorded as 20.6, 6.66 and 10.60, respectively at pod formation stage of toria. There was hardly any visible incidence as well as damage by rodents at the early stage of the crop development. The predominant species recorded were *B. bengalensis, Rattus* spp, *Mus* spp., *Bandicota indica* and *Dremomys lokriah*

Table 3. Incidence of rodents in pulse –toria cropping system (2013-15)

Crops	Crop stage	LBC/ha	TI	Damage (%)
Black gram	Vegetative	12.60	4.41	3.20
	Flowering	18.80	6.62	6.80
	Pod formation	24.60	8.88	12.20
Toria	Vegetative	-	-	-
	Flowering	14.60	3.86	6.20
	Pod formation	20.60	6.66	10.60

1.4. Rice-vegetables cropping system

The highest tiller damage (14.86%) and LBC/ha (38.60) was recorded at the harvesting stage of rice .Incidence of rodents in *rabi* vegetables in rice-vegetables cropping system was recorded (Table 4). Among the vegetables grown after *sali* rice ,the highest incidence in terms of live burrow count (LBC) was recorded in pumpkin (36.60) followed by potato(34.40) , pea (29.90) , brinjal (28.80) and carrot (24.00). Among the vegetables, the highest damage was recorded in potato (14.46%) followed by pea (14.00 %), pumpkin (12.20%). In other vegetables, the LBC/ha recorded revealed the presence of *B. bengalensis* but did not do heavy damage to the vegetables (Table 4).

Table 4. Incidence of rodents in rice -vegetables cropping system (2013-15)

Crops	LBC/ha	Damage (%)
Rice	38.60	14.86
Pumpkin	36.60	12.20
Potato	34.40	14.46
Pea	29.90	14.00
Tomato	20.40	6.60
Brinjal	28.80	8.62
Beet	18.80	8.60
Carrot	24.00	6.66

2. MONITORING OF RODENT ABUNDANCE AND DAMAGE IN DIFFERENT AGRO CLIMATIC ZONES OF ASSAM

2.1. Monitoring of rodent incidence at Lower Brahmaputra Valley Zone (LBVZ) of Assam

In Lower Brahmaputra Valley Zone, the highest damage was recorded in sugarcane (14.0%) and the lowest damage was recorded in beet (7.6%). More than 10.0% damage was recorded in toria (10.2%), buck wheat (12.6%), summer rice (10.6%), niger (12.8%), sweet potato (12.2%).Similarly, the highest LBC was recorded in niger (26.6) followed by sugarcane (22.4), summer rice (20.7), sweet potato (20.6) and toria (20.6). The recorded rodent species were *Bandicota bengalensis*, *B. indica*, *Rattus sikkimensis*, *Rattus rattus*, *Mus musculus* and *Dremomys lokriah*.

2.2. Monitoring of rodent incidence at North Bank Plain Zone (NBPZ) of Assam

In North Bank Plain Zone of Assam the highest damage was recorded in potato (14.60%), followed by sugarcane (14.2%), pumpkin (14.0%), beet (12.68%) and pea (12.70%). In knolkhol, radish, tomato, carrot and brinjal, the damage percentage was in between 4.08 -7.80% .Similarly, the highest LBC/ha was recorded in sugarcane (22.6) followed by potato (16.62), pumpkin (14.00), pea (12.67), beet (11.60). In knolkhol, radish, tomato, carrot, brinjal, the LBC/ha was in between 5.67-7.90. The predominant rodent species were *B. bengalensis*, *B. indica*, *Rattus sikkimensis*, *Rattus rattus* and *Mus musculus.*

3. EVALUATION OF BOTANICALS AGAINST RODENT PESTS FOR ANTIFEEDANT /DETERRENT/ ATTRACTANT EFFECTS

3.1. Antifeeding effects of Polygonum (*Polygonum hydropiper*) against *Bandicota bengalensis*

The results presented in Table 5 reveal that antifeeding index of polygonum treated baits increased with the increase of its concentration *i.e* 32.56%, 34.06% and 72.89 %, respectively at 2, 3 and 5% treated baits. Mean daily consumption (g/100gbw) of bait was recorded separately for pre treatment, during treatment and post treatment periods for 5 days. In the no choice feeding trial, the data (Table 6) recorded on *B. bengalensis* revealed that the lowest bait consumption (3.26 g/100 g bw) was recorded in polygonum (5%) followed by polygonum 3% (4.11 g/100g bw) and polygonum 2% (4.32 g/100g bw).The bait consumption at post treatment period revealed that some deterrent effect of polygonum on *B. bengalensis* as in all the treatments, bait consumption was low as compared to the pre treatment bait consumption. The highest antifeeding index of 56.31% was recorded at polygonum 5% followed by polygonum 3% (43.60 %) and polygonum 2 %(41.40 %).

Table 5. Antifeeding effect of Polygonum (Polygonum *hydropiper*) against *Bandicota bengalensis* (choice test)

Conc. in bait (%)	Mean daily consumption of food (g/100g body weight)±SE				AI (%)
	Pre treatment	During treatment		Post treatment	
		Plain bait	Treated bait		
2	8.11±0.41	3.46±0.41	1.76±0.26	5.60±0.76	32.56
3	8.66±0.72	3.66±0.46	1.80±0.42	5.80±0.86	34.06
5	8.46±0.82	7.40±0.56	1.16±0.33	4.60±0.72	72.89
Control	8.40±0.68	8.36±0.72	-	7.66±0.82	

Table 6. Antifeeding effect of Polygonum (*Polygonum hydropiper*) against *Bandicota bengalensis* (no choice test)

Conc. in bait (%)	**Mean daily consumption of food (g/100g body weight))±SE**			**AI (%)**
	Pre treatment	**During treatment**	**Post treatment**	
2	7.02±0.52	4.11±0.66	5.50±0.47	41.40
3	7.66±0.47	4.32±0.56	6.12±0.64	43.60
5	7.46±0.44	3.26±0.46	4.80±0.66	56.30
Control	8.10±0.56	7.66±0.51	7.46±0.53	

3.2. Antifeeding effects of Jatropha (*Jatropha curcus*) against *Rattus rattus*

The results reveal that the mean daily consumption of treated bait was low than that of untreated bait with antifeeding index of 18.24, 31.17 and 53.87 % in 2, 3 and 5% *Jatropha curcus* in bait, respectively (Table 7). In no choice feeding trial, the data recorded on *R. rattus* revealed that the lowest bait consumption (4.26 g/100g bw) was recorded with jatropha at 5% followed by jatropha 3%(5.10 g/100g bw) and jatropha 2%(5.50 g/100g bw).The antifeeding index of 44.30% was recorded with jatropha 5% whereas in jatropha 3 and 2%, the antifeeding index was 28.10 and 28.5%, respectively (Table 8). Between Jatropha 2 and 3%, the antifeeding index was recorded almost equal.

Table 7. Antifeeding effect of Jatropha (Jatropha *curcus*) against *Rattus rattus* (choice condition)

Conc. in bait (%)	Mean daily consumption of food (g/100g body weight) Mean±SE				AI (%)
	Pre treatment	During treatment		Post treatment	
		Plain bait	Treated bait		
2	7.20±0.66	4.11±0.24	3.36±0.73	5.82±0.42	18.24
3	6.92±0.53	4.01±0.36	2.76±0.66	4.66±0.54	31.17
5	7.11±0.87	4.64±0.41	2.14±0.86	3.26±0.44	53.87
Control	6.80±0.66	6.07±0.33	-	6.66±0.51	

Table 8. Antifeeding effect of Jatropha (Jatropha *curcus*) against *Rattus rattus* (no-choice condition)

Conc. in bait (%)	Mean daily consumption of food (g/100g body weight)Mean ±SE			AI (%)
	Pre treatment	During treatment	Post treatment	
2	7.70±0.32	5.50±0.46	6.60±0.33	28.50
3	7.10±0.36	5.10±0.41	6.10±0.41	28.10
5	7.66±0.28	4.26±0.52	5.66±0.46	44.30
Control	8.11±0.33	7.66±0.56	7.30±0.38	

3.3. Antifeeding effects of *Laportea crenulata* and *Mucuna prurita* against *Bandicota bengalensis* under laboratory condition

In this experiment, the cake was prepared by dried powder of *Laportea crenulata and Mucuna prurita* at 5% + rice powder +molasses and was offered to *B. bengalensis* under no choice condition. Pre- baiting was done by supplying cake with rice powder and molasses. The results (Table 9) reveal that the consumption of bait (g/100g bw) was 3.36 g during treatment whereas in post treatment period, the consumption of bait was low (1.10g).

In case of *Laportea crenulata*. The antifeeding index of 67.26% was recorded with *L. crenulata*. Another herbs, *M. prurita* had shown very encouraging results as the bait consumption of 3.10 g/100g bw was recorded during treatment but after treatment, the bait consumption was significantly low (0.86g) with antifeeding index of 72.25%. It has been noticed that after ingestion of treated bait, the neck and mouth portion of rodents was getting swallowed and rodents died within 5-10 days.

Table 9. Antifeeding effect of *Laportea crenulata and Mucuna prurita* against *Bandicota bengalensis* under laboratory condition

Botanicals	Mean daily consumption (g/100g body weight))±SE			AI (%)
	Pre-treatment	During Treatment	Post treatment	
Laportea crenulata	8.66±0.86	3.36±0.48	1.10±0.32	67.26
Mucuna Prurita	8.24±0.82	3.10±0.41	0.86±0.28	72.25
Control	8.40±0.76	8.16±0.54	8.24±0.33	

4: EVALUATION OF CHEMICAL COMPOUNDS FOR TOXIC AND ANTIFERTILITY PROPERTIES FOR DATA GENERATION ON INDIAN RODENTS

Botanicals *viz*.papaya seed powder,kutahi bengana seed powder,pine apple leaf powder,roots of sajana,neem seed powder at 5% in bait formulation were evaluated to see the toxicity as well as the antifertility properties againsr *Bandicota bengalensis.* The trials are in progress.

5:DEVELOPMENT OF RODENT MANAGEMENT TECHNOLOGIES UNDER STORAGE CONDITIONS

5.1. Rodent management in stores

Five grain stores each of equal size and infested with rodents were selected. .The treatments were (i) bromadiolone (0.005%) baiting followed by trapping (ii) bromadiolone (0.005%) baiting followed by application of ecodon (iii) bromadiolone (0.005% baiting) alone (iv) ecodon alone and (v) untreated control. The pre and post treatments consumption of plain baits (rice + mustard oil) revealed that application of bromadiolone and ecodon gave highest (76.84%) reduction in rodent activities followed by bromadiolone +trapping (60.36%). The single application of bromadiolone and ecodon gave 32.81 and 28.26 per cent reduction in rodent activities in stores (Table 10).

Table 10. Reduction in rodent activity in store (grain) after treatments

Treatments	Bait Consumption (g)		Reduction in rodent activities (%)
	Pre control	Post Control	
Bromadiolone+ Trapping	20.22	8.01	60.36
Bromadiolone +Ecodon	18.66	4.32	76.84
Bromadiolone	18.90	12.70	32.81
Ecodon	20.66	14.82	28.26
Control	18.66	18.98	-

5.2. <u>Effect of rodenticides and botanicals in rodent activities in store and Kaccha house</u>

Bromadiolone (0.005%) was evaluated against rodent incidence in store(grocery shops) .The pre control data (Table 11) revealed 14.4 g bait consumption and 88.20 per cent tracking index whereas the corresponding data in control was 16.60g and 84.40% tracking index. The data recorded on rodent activity at post treatment period after 1st ,2nd and 3rd pulse revealed a reduction of 41.66-77.08 % bait consumption as well as 31.29-86.84 % reduction of tracking index due to application of bromadiolone in minimal baiting techniques.

Table 11. Effect of bromadiolone (0.005%) pulse baiting in rodent activities in stores

Treatments	Census method	Pre-control	Reduction in relative activity		
			Post treatment		
			Pulse I	Pulse II	Pulse III
Bromadiolone	Bait consumed(g) Tracking Index (%)	14.40 88.20	8.40(41.66) 60.60(31.29)	6.60(54.16) 32.20(63.38)	3.30(77.08) 11.60(86.84)
Control	Bait consumed(g) Tracking Index (%)	16.60 84.40	16.89 86.80	18.20 80.40	16.66 84.00

(Figures in the parenthesis indicate per cent reduction in relative activity at each pulse treatment)

The data recorded in Table 12 on rodent activities in kaccha house reveal that pre control bait consumption recorded was 16.20 g and pre control tracking index was 82.20%. Due to application of botanical castor based rodenticides (Ecodon) at time interval the reduction of rodent activity in terms of census bait ranged from 35.18-60.37% and reduction of tracking index ranged from 26.87-77.37 % at different time intervals whereas in control during the treatment period, the rodent activity in terms of bait consumption and tracking index was almost uniform and infestation was heavy.

Table 12. Effect of botanical in rodent activity in kaccha house

Botanicals	Census method	Pre-control	Reduction in relative activity		
			Post treatment		
			Pulse I	Pulse II	Pulse III
Ecodon	Bait consumed(g) Tracking Index (%)	16.20 82.20	10.50(35.18) 60.11(26.87)	8.10(50.00) 40.0(51.33)	6.42(60.37) 18.60(77.37)
Control	Bait consumed(g) Tracking Index (%)	14.60 84.40	14.80 82.20	16.60 86.60	16.22 84.40

(Figures in the parenthesis indicate per cent reduction in relative activity at each pulse treatment)

6. BIO-ECOLOGY OF MAJOR RODENT SPECIES (*BANDICOTA BENGALENSIS*)

6.1. Population fluctuation of lesser bandicoot rat, *B. bengalensis*

Highest live burrow/ha was recorded in the month of October (44.20) followed by November (40.66) and December (36.20). The lowest live burrow was recorded in the month of February (12.20 numbers /ha). During the observation, it was recorded that the numbers of live burrow per hectare decreased gradually from November (40.66) up to the month of March (16.20). The activity of *B. bengalensis* increased gradually from the month of March (16.20 numbers /ha) up to the month of October at which it was recorded as maximum.

The highest trap index of 8.80 trapped rodents / 100 traps / night was recorded in the month of September followed by October (7.26) and May (7.00). The lowest trap index of 1.10 was recorded in the month of January followed by February (1.20). Like live burrow density, trap index also increased gradually from the month of March (2.24) up to the month of October (7.26) and again it decreased gradually from the month of November (6.20) up to the month of January and February.

Monthly rodent population in terms of live burrow count /ha and trap index revealed that during *sali* rice i.e., August to December, the maximum rodent population in terms of LBC/ha and trap index was recorded. This may be due to the available source of food from *sali* rice. From January to April, the LBC/ha (range 12.60 to 20.30 numbers/ha) and trap index (1.10 to 6.66) were recorded.. During the month of May to June, the rodent incidence in terms of LBC/ha (28.60 to 20.20 numbers/ha) and trap index (7.00 to 6.20) was recorded and as may be due to the *summer rice* grown in the field.

6.2. Distribution of rodent burrows in the rice field (*sali* rice)

The distribution of burrows on bund, bigger bund (*bongia*) and inside the field was recorded at different crop growth stages. No rodent burrows were recorded inside the field during tillering and panicle initiation stage. In the tillering stage the mean distribution of burrows per 100 running meter of bund and *bongia* were 14.00 and 46.6 respectively. In the panicle

initiation stage on bund, the number of burrows recorded was 28.40 whereas on big bund it was recorded 40.40. On the ripening stage 64.00 number of burrow was recorded on the bund whereas on the big bund and inside the field the number of burrows recorded was 22.6 and 20.66 respectively. In the harvesting stage the distribution of burrows was 76.2, 16.20 and 46.00 on bund, big bund and inside the field respectively.

6.3. Distribution of rodent burrows in the rice field

The distribution of rodent burrows on bund, big bund (bongia) and field was recorded at different crop growth stages during *boro* rice. No rodent burrows were recorded inside the field during the crop growth stages. In all the crop growth stages, the LBC in bongia (big bund) was higher in comparison to bund.

6.4. Reproduction and breeding biology of *B.bengalensis*

In the field of *sali* rice, sherman traps were placed in the front of live burrows in the month of September, October and November. The field collected rodents were sexed, weighed and measured morphometrically (Table 13).

The field collections included bandicoots of all ages as evident from their body weights which ranged between 20 gm to 250 gm (in males) and 10-275 gm (for females) .Bimonthly collection during 2013-14 in *sali* rice revealed maximum body weight of 275 gm in adult female and 250 gm in case of adult male bandicoots with highest body weight were trapped in the month of October-November where as juveniles and young ones have been recorded in the month of December (Table 13)

Table 13. Morphometric measurement of *B. bengalensis*

Rodents	HB (cm)	Tail (cm)	Weight (gm)
Adult Female	19.64	14.65	275.66
Adult Male	21.22	14.12	250.90
Female young	12.04	10.66	50.43
Male young	7.51	5.50	20.21
Female juvenile	4.67	4.96	10.54

During *kharif* season, the rodent incidence in rice was monitored in terms of trapping index and LBC /ha and the data revealed that the highest trap index (14.82) and LBC/ha (33.31) were recorded at the harvesting stage of the rice crop. The indices related to rodent activity increased with the advancement of the crop growth stages from maximum tillering to harvesting stage. The rodents were collected from rice field and they were differentiated as male and female on the basis of anogenital space, which is greater in male. The female rodents were tested whether they were pregnant or not by observing mammary gland. The sex ratio (M: F) was greater in harvesting stage followed by reproductive and maximum tillering stage of the rice crop. The pregnancy percentage was greater in the reproductive stage of paddy crop followed by harvesting stage. No pregnancy was recorded in maximum tillering stage of the crop (Table 14)

Table 14. Breeding parameters of *B. bengalensis* during *kharif* rice, 2014-15

Crop growth stages	Trap index	Live burrow count (No. /ha)	Sex ratio (M: F)	Pregnancy (%)
Maximum tillering	6.71	10.46	1:0.86	0.00
Reproductive stage	8.42	18.72	1:1.12	40.26
Harvesting stage	14.82	33.31	1:1.26	26.41

In *rabi* vegetables the highest trapping index was recorded in the month of February (6.66) followed by March (6.02). During the month of December –January the trapping index was comparatively low (2.26-3.40). More female rodents were trapped than males during the month of December- January whereas in the month of February- March, more males were trapped than females. No pregnancy was recorded in the month of December-January but in the month of February-March, the pregnancy percentage was 26.6-40.8 %(Table 15).

Table 15. Breeding parameters of *B. bengalensis* in *rabi* vegetables, 2014-15

Months	TI	Sex ratio (M: F)	Pregnancy (%)
December	2.26	1:1.06	-
January	3.40	1:1.11	-
February	6.66	1:0.92	26.6
March	6.02	1.0.86	40.8

7. DEVELOPMENT OF INTEGRATED RODENT MANAGEMENT MODULES IN PREDOMINANT CROPPING SYSTEMS

7.1. Effect of botanical, rodenticides and trap on the incidence of rodents in *sali* rice

The effect of different treatments on rodent incident in terms of live burrow count (LBC/ha) and trapping index (TI) in case of *sali* rice was worked out and presented in Table 16. The per cent reduction in rodent population due to spraying of ecodon (1:50) on bund at maximum tillering and just before panicle initiation stage was 50.04 per cent LBC/ha and 45.35 per cent trapping index and spraying of ecodon (1:50) on bund at maximum tillering and just before panicle initiation stage + sherman trap (30 traps/ha) after 10 days of last application recorded reduction of 77.44 per cent LBC/ha and 58.01 per cent trapping index respectively (Table 16). Application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage recorded reduction of 67.69 per cent LBC/ha and 50.11 per cent trapping index, and application of ecodon solution @ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps/ha) after 10 days of last application recorded the highest reduction in rodent population i.e. 87.52 per cent LBC/ha and 67.20 per cent trapping index. Baiting with zinc phosphide (2.5%) at just before panicle initiation stage + sherman trap (30 traps/ha) after 10 days of last application recorded reduction of 73.11 per cent LBC/ha and 54.05 per cent

trapping index. The placement of sherman traps (30 traps/ha) at maximum tillering stage, just before panicle initiation stage and 10 days after panicle initiation stage recorded minimum reduction of rodent population i.e. 35.52 per cent LBC/ha and 21.92 per cent trapping index The data recorded on control revealed that rodent population in terms of LBC/ha and trapping index increased with an advancement of crop. The LBC/ha (10.66) was recorded at maximum tillering stage increased to 25.66 at milky stage where as trap index of 4.53 was recorded at maximum tillering stage increased to 9.06 at milky stage.

7.2. Effect of botanical, rodenticides and trap on the incidence of rodents in *boro* rice

The per cent reduction in rodent population in terms of live burrow count (LBC/ha) and trapping index (Number of rodents trapped/100 traps/night) was worked out and presented in Table 17. The per cent reduction in rodent population due to spraying of ecodon (1:50) on bund at maximum tillering and just before panicle initiation stage was 56.52 per cent LBC/ha and 44.94 per cent trapping index and spraying of ecodon (1:50) on bund at maximum tillering and just before panicle initiation stage + sherman trap (30 traps/ha) after 10 days of last application was 78.32 per cent LBC/ha and 60.11 per cent trapping index respectively. Application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage recorded reduction of 68.06 per cent LBC/ha and 51.78 per cent trapping index whereas, the application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps/ha) after 10 days of last application showed the best treatment with the highest reduction in rodent population (90.99 per cent LBC/ha and 68.11 per cent trapping index). Application of zinc phosphide (2.5%) baiting at just before panicle initiation stage + sherman trap (30 traps/ha) after 10 days of last application recorded reduction of 71.75 per cent LBC/ha and 55.16 per cent trapping index. The placement of sherman trap (30 traps/ha) at maximum tillering stage, just before panicle initiation stage and 10 days after panicle initiation stage recorded minimum reduction of rodent population (34.64% LBC/ha and 25.89% trapping index). The data recorded on control revealed that rodent population in terms of LBC/ha and trapping index increased on upward trend as the crop stage advanced. The LBC/ha (8.33) was recorded at maximum tillering stage increased to 23.66 at milky stage where as trapping index of 3.53 was recorded at maximum tillering stage increased to 7.33 at milky stage.

7.3. Effect of botanical, rodenticides and trap on cut tillers damage in *boro* and *sali* rice

The data recorded on rodent damage in terms of per cent cut tillers during both *boro* and *sali* rice is presented in Table 18. The results revealed that all the treatments were found effective against *Bandicota bengalensis* in reducing the damage in the field. The treatment with application of ecodon solution @ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps/ha) after 10 days of last application was found to be most effective in reduction of cut tillers damage in both the season i.e. 75.16 per cent in *boro* and 73.10 per cent in *sali* rice. The next best treatment was spraying of ecodon (1:50) on bunds at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps/ha) after 10 days of last application which recorded 69.05 per cent reduction in cut tillers in *boro* rice and 67.13 per cent reduction in cut tillers in *sali* rice. Baiting with zinc phosphide (2.5%) at just before panicle initiation stage + sherman

trap (30 traps/ha) after 10 days of last application recorded 65.06 per cent reduction in cut tillers in *boro* rice whereas, in *sali* rice, the cut tillers reduction percentage was 62.09. Application of ecodon solution @ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage recorded 53.11 per cent and 52.14 per cent reduction of cut tillers in *boro* and *sali* rice respectively, where as spraying of ecodon (1:50) on bunds at maximum tillering stage and just before panicle initiation stage recorded 43.99 per cent reduction in cut tillers in *boro* rice and 41.03 per cent reduction in cut tillers in *sali* rice. The placement of sherman trap (30 traps/ha) at maximum tillering stage, just before panicle initiation stage and 10 days after panicle initiation stage showed minimum reduction of cut tillers i.e. 16.11 per cent in *boro* rice and 14.19 per cent in *sali* rice, respectively . The data recorded on control revealed that rodent damage in terms of per cent cut tillers increased with an advancement of crop growth stage in both the seasons. The per cent cut tillers of 4.26 and 4.73 recorded at maximum tillering stage in *boro* and *sali* rice respectively, increased to 8.17 and 10.77 per cent cut tillers at milky stage in *boro* and *sali* season respectively.

Table 16 . Effect of different treatments on live burrow count (LBC) and trap index (TI) in *sali* rice

Treatments	Pre-treatment		Post-treatment		Reduction in population (%)	
	LBC/ha	TI	LBC/ha	TI	LBC/ha	TI
T_1 : Spraying of ecodon (1:50) on bunds at maximum tillering stage and just before panicle initiation stage	11.33	4.63	5.66	2.53	50.04	45.35
T_2 : Application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage	11.33	4.33	3.66	2.16	67.69	50.11
T_3 : Spraying of ecodon (1:50) on bunds at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	10.33	4.43	2.33	1.83	77.44	58.01
T_4 : Application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	10.66	4.36	1.33	1.43	87.52	67.20
T_5 : Zinc phosphide (2.5%) baiting at just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	17.33	6.66	4.66	3.06	73.11	54.05
T_6 : Sherman trap (30 traps / ha) at maximum tillering stage, just before panicle initiation stage and 10 days after panicle initiation stage	10.33	4.56	6.66	3.56	35.52	21.92
T_7 : Control	10.66	4.53	25.66	9.06		
S.Ed.(±)	0.75	0.20	0.39	0.14		
CD (P=0.05)	1.64	0.45	0.86	0.31		

LBC= Live burrow count, TI= Trap index

Table 17. Effect of different treatments on live burrow count (LBC) and trap index (TI) in *boro* rice

Treatments	Pre-treatment		Post-treatment		Reduction in population (%)	
	LBC/ha	TI	LBC/ha	TI	LBC/ha	TI
T_1 : Spraying of ecodon (1:50) on bunds at maximum tillering stage and just before panicle initiation stage	7.66	3.56	3.33	1.96	56.52	44.94
T_2 : Application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage	8.33	3.36	2.66	1.62	68.06	51.78
T_3 : Spraying of ecodon (1:50) on bunds at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	7.66	3.36	1.66	1.34	78.32	60.11
T_4 : Application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	7.33	3.23	0.66	1.03	90.99	68.11
T_5 : Zinc phosphide (2.5%) baiting at just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	15.66	5.13	4.66	2.30	71.75	55.16
T_6 : Sherman trap (30 traps / ha) at maximum tillering stage, just before panicle initiation stage and 10 days after panicle initiation stage	8.66	3.63	5.66	2.83	34.64	25.89
T_7 : Control	8.33	3.53	23.66	7.33		
S.Ed.(±)	0.67	0.24	0.17	0.11		
CD (P=0.05)	1.47	0.53	0.38	0.25		

LBC = Live burrow count, TI = Trap index

Table 18. Effect of different treatments on per cent cut tillers in *boro* and *sali* rice

Treatments	Cut tillers (%)				Reduction in cut tillers (%)	
	Pre-treatment		Post-treatment			
	***boro* rice**	***sali* rice**	***boro* rice**	***sali* rice**	***boro* rice**	***sali* rice**
T_1 : Spraying of ecodon (1:50) on bunds at maximum tillering stage and just before panicle initiation stage	4.16	4.63	2.33	2.73	43.99	41.03
T_2 : Application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage	4.33	4.66	2.03	2.23	53.11	52.14
T_3 : Spraying of ecodon (1:50) on bunds at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	4.46	4.93	1.38	1.62	69.05	67.13
T_4 : Application of ecodon solution@ 1 litre/burrow at maximum tillering stage and just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	4.43	4.76	1.10	1.28	75.16	73.10
T_5 : Zinc phosphide (2.5%) baiting at just before panicle initiation stage + sherman trap (30 traps / ha) after 10 days of last application	9.13	9.63	3.19	3.65	65.06	62.09
T_6 : Sherman trap (30 traps / ha) at maximum tillering stage, just before panicle initiation stage and 10 days after panicle initiation stage	4.53	4.86	3.08	4.17	16.11	14.19
T_7 : Control	4.26	4.73	8.17	10.77		
S.Ed. (±)	0.50	0.39	0.28	0.15		
CD (P=0.05)	1.09	0.86	0.61	0.32		

7.4. Effect of Ecodon solution in the rice field

The l castor based botanical rodenticides (Ecodon) was sprayed on bunds during tillering stage in the evening hours. Before treatment, the bunds were made weed free and made moist by spraying water. Observations on LBC and TI before treatment and after 1, 2, 3 and 4th week of treatment was recorded. The results reveal that the rodent population reduced to 55.5 and 54.4 % in terms of LBC and TI after I week of treatment. The reduction of rodent population in terms of LBC and TI was 54.5 and 41.6 %, respectively after 2weeks of treatment. On 3rd week, the reduction per cent of rodent population in terms of LBC and TI was comparatively low i.e. 30.7 and 29.4%, respectively. The spraying of Ecodon could not give protection in rodent population after 2nd week as it was evidenced from the decreasing trend of reduction percentage. (Table 19)

Table 19. Effect of Ecodon in the incidence of rodents in rice field

Treatments	LBC/ha					TI				
	1 DBT	1 WAT	2 WAT	3 WAT	4 WAT	1 DBT	1 WAT	2 WAT	3 WAT	4 WAT
Ecodon (1:50)	14.2	8.6	10.5	18.2	22.2	4.1	2.1	2.8	3.6	4.3
Control	16.4	18.2	22.8	26.1	28.6	4.4	4.6	4.8	5.1	5.4
Reduction (%)	-	55.5	54.5	30.7	21.5	-	54.4	41.6	29.4	20.4

DBT-days before treatment *WAT-weeks after treatment*

7.5 Effect of Ecodon granules in the rice field

A castor based rodent repellent in granule formulation was evaluated against rodent incidence in rice fields .The rodent incidence was measured using burrow count and trap index methods. Plots measuring 100x50 m dimension was taken for the study in 6 replications with 1 control plot, wherein the treatment of rodent repellent granules was not given. The ecodon granules mixed in sand @1:5 proportions was broadcasted along the bunds of the plots. . The ecodon was applied on the bunds at the tillering stage. The average number of burrows recorded on pre treatment period in the treated plot was 12.66 which were significantly reduced to 8.20 repellent treated experimental plots. Similarly significant reduction in trap index from 3.81 to 3.06 was also recorded in the trapped rodents. (Table 20).Due to application of botanical granules the per cent reduction of LBC and TI was 69.42 and 63.62 per cent, respectively.

Table 20. Effect of repellent (Ecodon granules) on rodent incidence in rice

Repellent	LBC		TI	
	Pre treatment	Post treatment	Pre treatment	Post treatment
Ecodon (granules)	12.66	8.20	3.81	3.06
control	12.14	26.82	3.96	8.41
% reduction		69.42		63.62

8. SOCIAL ENGINEERING ACTIVITY ON RODENT PEST MANAGEMENT AS PARTICIPATORY ADAPTIVE RESEARCH IN ADOPTED VILLAGES

8.1. Social engineering activities during 2013-15

The site for social engineering activity was selected at Malowkhat, Dhekorgora block under Jorhat Sub division. Malowkhat is situated near the bank of the river Bhogdoi, a tributary of the river the Brahmaputra. Two villages namely Gogoigaon and Bhogdoiporia were selected as adopted and partially adopted villages respectively. Another village was kept as control village. In adopted village, training, method demonstration as well as inputs was supplied but in case of partially adopted village only training was provided. The major cropping system of the adopted villages was Rice-vegetables.

In the beginning of the *sali* season initial rodent population in terms of LBC/ha and Trap index from the villages were recorded. Then, in the village Gogoigaon, rodent control measures along with training on rodent pest management were provided. All the villagers participated in the training programme. In the control village, no inputs or training was provided and only data on rodent infestation were recorded.

The data indicates that rodent infestation increased gradually from tillering stage and reached a peak during the harvesting stage of the crop. In the adopted village however rodent infestation decreased from PI stage of the crop. The LBC in the control plot was 12.4 during tillering stage of the crop which increased up to 46.4 at harvesting stage, while in the adopted village LBC was 11.4 at tillering stage and increased up to 18.6 at PI stage and then decreased again to 14.2 at harvesting due to intervention in terms of application of rodenticides (Zinc phosphide and Bromadiolone baiting).Similar trends were also observed in case of Trap Index and Cut tillers damage (Table 21)

Table 21. Live burrow count (LBC), Trap index (TI) at different crop stages of *Sali* rice at social engineering site at Malowkhat, 2013-15

Crop stage	LBC/ha		TI	
	V1	V2	V1	V2
Maximum tillering	11.40	12.40	6.40	6.11
Ripening	18.60	20.80	8.70	12.69
Harvesting	14.20	46.40	6.66	16.66

V1: Adopted village V_2: Control village

The cut tillers damage was also recorded in both villages. In the adopted village, 3.90 % tillers damage was recorded at the maximum tillering stage and at ripening stage (8.06%) cut tillers damage was recorded. On the other hand, the per cent tillers damage increased with the advancement of the phonological stages of the crop in control one (Table 22).

Table 22. Damage in different crop stages of rice at Social Engineering Site

Crop stage	Rodent damage (% cut tillers)	
	V1	V2
Max. tillering stage	3.90	4.20
Ripening	8.06	10.10
Harvesting stage	6.66	16.60

V_1-Adopted Village V_2-Control Village

The results (Table 23) of the farmers participating approach in rice vegetables cropping system indicated that there was a reduction of rodent population of 80.23% LBC (34.2-6.8 LBC) and TI by 60.86 %(4.6-1.8 TI) in different vegetables grown in the adopted village. In the semi adopted village, the reduction in rodent density was 50.27% (i.e. from 36.6-18.2 LBC/ha) and the TI of 54.41% (*i. e.* 6.8-3.1 TI) whereas in control village, there was an increase in rodent density both in terms of LBC and TI.

Table 23. Live burrow count (LBC), Trap index (TI) in different crop stages of *vegetables* at social engineering site at Malowkhat, 2013-15

VEGETABLES			
	V1	V2	V3
LBC/ha a)Pre treatment b) Post treatment	 34.4 6.8	 36.6 18.2	 33.5 38.2
% control success	80.23	50.27	
TI a)Pre treatment b) Post treatment	 4.6 1.8	 6.8 3.1	 4.8 8.6
% control success	60.86	54.41	

V1: Adopted Village V2: Partially Adopted V3: Control

8.2. Impact Assessment of Farmers Participating Adaptive Research under Social Engineering

A survey was conducted before and after the treatment in rice -vegetable cropping system to know the impact of education and training in the form of per cent adoption of different practices. Data reveals different levels of adoption for different practices (Table 24). Before training farmers were not practicing rodent control in the rice field .Only some farmers used anticoagulants rodenticides to kill rodents in their store, house, etc. but after education in the form of training and demonstration, 53.3% farmers started practicing rodent control with zinc phosphide. Before education, farmers were not aware about pre baiting incase of zinc phosphide, but after training, they practiced pre baiting. The farmers were demonstrated about the use of local bamboo traps to control rodents, their placement in the rice field. It has been

revealed that 46.6% farmers used bamboo traps after training and demonstration and 40% farmers used mechanical traps in the field. Most of the farmers were aware about anticoagulant rodenticides and they frequently used rodenticides against rodents in their houses, store etc.

Table 24. Impact assessment of farmers participating adaptive research under social engineering activities

Sl No	Rodent control practices	% adoption	
		Before	After
1	Doing regular rodent control in field crop	0.00	53.3
2	Doing regular rodent control other than crop field	22.2	80.0
3	Use anticoagulant	35.5	40.0
4	Poison baiting in the crop field	0.0	0.0
5	Poison baiting in the lean period	0.0	26.6
6	Doing pre-baiting in case of acute rodenticides	0.0	46.6
7	Use bait station	0.0	0.0
8	Use local bamboo traps	0.0	46.6
9	Use of mechanical traps	0.0	40.0
10	Doing weeding	0.0	13.4
11	Treatment in surrounding area/vacant lands	0.0	11.2
12	Collection of remaining poisons bait	0.0	0.0
13	Washing of traps before reuse	0.0	57.7
14	Collection of dead rodents	0.0	55.6

9. STUDIES ON PREDATORY POTENTIAL OF BARN OWLS AND ITS UTILIZATION FOR BIO-CONTROL OF RODENT PESTS

Common Name: Barn owl

Scientific Name: *Tyto alba*

Family: Tytonidae

Food habit*:* *B bengalensis*: 34%, *R. rattus (12%),R. spp. (20%) , T. indica (0.5%) ,Mus sp (11%),* Others (10%)

A barn owl nest box was made of wood having floor size of 35 cm x 35 cm, height of 45 cm with an entrance hole of 15 cm x 15 cm at a height of 15 cm on the front cover of the box with a 15 cm floor at bottom of the box with a roof cover (lid) with provision of two wings at the top of the back cover for hanging or fixing on substrate (Table 25). Five numbers of such boxes were installed in the top of the tree trunk in various localities of Jorhat in the month of October-November, 2013.The barn owl took shelter inside the nest boxes, but it did not inhabit permanently in the box.

Table 25. Barn owl nest box

Type of nest box	Box size	Installation	Time of installation
Wooden	Floor= 35cmx 35 cm Height= 45cm with an entrance hole of 15cm x15 cm at a height of 15 cm on the front cover of the box with a 15 cm floor at bottom of the box with a roof cover (lid) with provision of two wings at the top of the back cover for hanging or fixing on substrate	Tree trunk, go down at the height of 15 feet	October-November

9.1. Effect of artificial nest boxes on rodent incidence

Six nest boxes were provided for artificial nesting and breeding of barn owl. Of them, in one nest box was used by barn owl for breeding and in two nest boxes were used by barn owls for roosting. Out of six installed in different locations. The locations were near paddy field, wheat field, ICR farms, and homestead garden. Thus, 50 % of the nest boxes were occupied by barn owls. Competition for nesting by common myna with barn owls has been noticed in artificial nest boxes. The pre and post treatment count of LBC revealed that due to installation of nest boxes for barn owl a control success of 40% and 23 % have been recorded in the crop fields of both rice and wheat respectively where as the success control was significantly higher in case of near buildings (55.5%) and homestead garden (53.8%) (Table 26)

Table 26. Effect of artificial nest boxes on rodent incidence

Locations	Pre treatment burrow count	Post treatment burrow count	% control success
Crop field (rice)	30	18	40.0
Crop field (wheat)	26	20	23.0
Near building	18	8	55.5
Homestead garden	26	12	53.8

9.2. Effect of artificial nest boxes on rodent incidence in different field crops

Artificial barn owl nest boxes made of wood and galvanized plain sheet were installed for nesting and breeding of barn owl. The nest boxes were installed at the top of the tree trunk, water tank, building etc. near the crop field of paddy, mustard, wheat and vegetables crops in their crop season. The barn owl took shelter inside the nest boxes but it did not inhabit permanently in the box. Competition for nesting by common myna with barn owls has been noticed in artificial nest boxes.

The pre and post treatment count of LBC in different crops revealed a 41.75% control success in case of rice. The control success in respect of LBC was recorded 31.13, 48.12 and 67.08%, respectively in case of mustard, wheat and vegetables (Table 27). The pre and post treatment records of TI reveal a control success of 55.81% in case of rice whereas the control

success in case of mustard, wheat and vegetables were 47.82, 47.16 and 56.36 %, respectively. From the results, it is obvious that the barn owl can be a good predator of the vertebrate pests of their area and it requires further investigations on long term basis for utilizing this predatory bird as a biocontrol agent against such pests.

Table 27. Effect of artificial nest boxes on rodent incidence

Particulars	Crop			
	Rice	Mustard	Wheat	Vegetables
LBC				
a)Pre count	36.4	21.2	32.0	18.8
b)Post count	21.2	14.6	16.6	6.2
% control success	41.75	31.13	48.12	67.02
TI				
a)Pre treatment	8.6	4.6	7.76	6.60
b)Post treatment	3.8	2.4	4.10	2.88
% control success	55.81	47.82	47.16	56.36

LOCATION SPECIFIC PROGRAMMES

1. COLLECTION, CATALOGUING AND EVALUATION OF LOCAL TRAPS

The trap index data presented in Table 28 reveal that a control success of 57.4% was achieved due to placement of local bamboo trap in case of rice .The control success in case of mustard and vegetables was 63.1 and 55.7%, respectively due to placement of local traps.

Table 28. Effect of local bamboo trap on rodent incidence

Parameter	Crops		
	Rice	Mustard	Vegetables
TI			
a)Pre count	9.66	8.42	6.60
b)Post count	4.11	3.11	2.92
% control success	57.4	63.1	55.7
LBC			
a)Pre count	32.2	26.2	22.8
b)Post count	18.4	14.4	8.6
% control success	42.8	45.0	62.2

A significant reduction of LBC /ha was also achieved due to trapping of rodents in the crop field. The control success of 42.8% was achieved in case of rice whereas in mustard and vegetables, the control success percentage in respect of LBC/ha was 45 and 62.2%, respectively. From the data it can be concluded that local traps may be an effective tools for the management of rodents in the crop field.

Table 29. Effect of trapping on the rodent incidence in *kharif* rice

Treatment	TI			
	Pre count	Tillering	PI	Flowering
Bamboo trap	4.52	3.65	8.92	10.94
Bandicoot Trap	4.45	3.42	7.48	9.75
t (0.05%)	0.30	2.90*	4.84*	8.40*

The Trap Index (TI) before placement of bamboo traps (4.52) and bandicoot trap (4.45) was no significant variation (t=0.30). The TI due to placement of bamboo traps at tillering stage (3.68), Panicle initiation stage(8.92) and flowering (10.94) and the placement of bandicoot traps at maximum tillering stage(3.42),panicle initiation(7.48) and flowering stage(9.75) show significant variation of bamboo traps over mechanical traps (t=2.90,4.84 and 8.40) (Table 29).

2. SEASONAL INCIDENCE OF *DREMOMYS LOKRIAH* IN PLANTATION CROP

Studies on incidence of *D. lokriah* in plantation crops was carried out in 2013-14 at four locations, viz., Borpathar (Kordoiguri), Baliaati (Garumora), Fishery Research Centre, AAU, Jorhat and Patiagaon. The monitoring was done at fifteen days interval. The damaged nuts fell into the ground and by observing the freshly fallen nut below the tree, it was ascertained that the trees were affected by squirrel. So, one person climbed up to the top portion of the tree and counted all the damaged nut attached to the pedicel and calculated the percent of damage in coconut. Prior to studies on species composition infesting coconut plantations in Assam farmers opinion about squirrel problem in fruit crops was sought, which is briefed as under;

Farmers' opinion can be summarized as:

- Squirrels infest mainly fruit crops like jack fruit, guava, pomegranate, litchi, pine apple and mainly coconut and areca nut.
- Squirrels activity has been seen throughout the year.
- They are active during day time only.
- Squirrels were observed to construct their nests above ground on different tree, bamboo plantation.
- They choose the place for nesting which seemed safer and away for disturbances of animals and human activities.
- In areca nut, squirrels attack tender nuts.
- In coconut, they make hole in the centre of the nut.

The observations indicated that *Dremomys lokriah* is a major problem species in coconut plantations in all the four study villages. In one of the locations i.e., Borpathar (Kordoiguri) *Rattus rattus* was also observed in the plantations. The squirrels made nests on coconut and bamboo trees and inflicted 3.66- 5.37% nut damage (Table 30)

Table 30. Rodent incidence in coconut in Assam

Village/Area (location)	Rodent specie s recorded	Nesting site	Activity	Rodent infestation (%)	Nut damage (%)
Borpathar (Kordoiguri)	*Rattus rattus*, *Dremomys lokriah* and Flying Squirrel	On the tree Bamboo plant	Throughout the year (Peak:May-August)	35.50	5.37
Nagaon-Jamuguri	*D. lokriah*	On the tree Bamboo plant Crevices in the buildings	Throughout the year (Peak: June-Sept)	32.62	4.67
FRC, AAU,Jorhat	*D. lokriah*	On the tree Crevices in the buildings	Throughout the year (May-August)	15.50	3.66
Baliatti (Gorumora)	*D.lokriah*	On the tree	Throughout the year		

The Squirrels infest mainly fruit crops like jack fruit, guava, pomegranate, litchi, pine apple and mainly coconut and areca nut. Squirrels were observed to construct their nests above ground on different tree, bamboo plantation. They seem to avoid traditional fruit trees for their nesting since majority of the nests were recorded on non fruiting trees. The nesting sites were recorded in different habitats from October to March .The squirrels choose the place of nesting which seemed safer and away from disturbances of animals and human activities. Field observations revealed that squirrels are active throughout the year during day hours but more active during morning(5.00 to 9.00am) and Evening (4.00 to 6.00 pm), The squirrels activities were more pronounced from June to September where their calls and running activities were more on the roof of the houses, boundary walls ,nearby trees etc. In areca nut, squirrels attack tender nuts. In coconut, they make hole in the centre of the nut.

Effect of castor based repellent (Ecodon): An observational trial (Table 31) was conducted with application of botanicals(ecodon) in different dilution (1:10) & (1:20) .The ecodon have been applied in the nuts as well as the crown after cleaning as well as spraying on the nuts. The higher concentration of ecodon *i. e* 1:10 dilution gave a control success of 46.91% and 33.53 % in case of rodent infestation and nut damage, respectively. Whereas the application of ecodon (1:20) gave a control success of 32.65 and 29.88 per cent in respect of rodent infestation and nut damage, respectively.

Table 31. Effect of botanical (Ecodon) on rodent infestation in coconut

Treatment	Pre treatment		Post Treatment		% control success	
	RI%	ND%	RI%	ND%	RI%	ND%
Ecodon(1:10) @ 1L/plant	38.42	6.62	20.40	4.40	46.91	33.53
Ecodon(1:20) @ 1L/plant	36.62	5.42	24.66	3.80	32.65	29.88

RI-rodent infestation ND-nut damage

Effect of anticoagulant rodenticides *vis a vis* Ecodon: In another field trial efficacy of wax blocks of bromadiolone and brodifacoum (0.005%) was studied in comparison to castor based repellent formulation (Ecodon**).** The rodenticides were used as crown baiting whereas, Ecodon was used as spray on the crown, nuts as well as around the tree trunk at the basal portion. Before starting of the trial, all the trees were numbered and all the squirrel damaged fallen nuts at the base of the tree were removed from the site so as to record the fresh damaged nuts. The bromadiolone and brodifacoum wax cakes were placed at the base of the panicle containing tender nuts. The baiting was done for three days. Observations were made for fallen nuts and nuts damaged after one month of the treatment.

It can be seen from the Table 32 that poison baiting with bromadiolone and brodifacoum (0.005%) yielded 66.6 and 57.4 % reduction of nut damage one month after treatment. While with Ecodon, the percentage reduction in nut damage /fallen nuts was 54.1%. Among the rodenticides, bromadiolone was found to be more effective in checking the squirrel damage in coconut as compared to brodifacoum and ecodon. However, this study needs further confirmation

Table 32. Effect of baiting on rodent infestation (nut) in coconut

Treatment	**Nut damage (%)**		
	Pre treatment	**Post treatment**	**Reduction**
Bromadiolone (0.005%)	12.6	4.2	66.6
Brodifacoum(0.005%)	10.8	4.6	57.4
Ecodon(1:10)	14.4	6.6	54.1

3. RODENT MANAGEMENT IN POULTRY FARMS

Rodent cause direct damage to poultry house structure, poultry feeds, chicks, and eggs .Rodent cause indirect damage by contamination and deterioration of poultry house environment and by spreading several diseases to poultry as well as farmers. The poultry farm premises provide the most favorable and stable habitat because of availability of abundant food from the feed. Poultry farms are poorly built and managed and are without proper rodent proof structures for storages of feed and eggs. *Rattus rattus* is the most predominant in poultry farms. Thatched and wooden roofs are often severely infested with house rats. The house mice, *Mus musculus* are frequently found on the ground in and around hoppers, feed bags, etc. The

Bandicota bengalensis which generally dig burrows in the peripheral vacant land in the poultry house are frequently attracted within the premises. They dig burrows in the foundation and floor and the some of the burrows may have opening on both inside and outside the poultry house. Accumulation of garbage and waste material around the premises provide good nesting and feeding ground to rodents. Usually farmers do not risk carrying out rodent control operations when the birds are in the premises. The most appropriate time to implement rat control operations in the poultry house would be when the birds are vacated at the end of the flock cycle. The studies were undertaken at four poultry farms. *R. rattus* was predominant in two farms, viz., Potiagaon (66%) and Nowboicha (56%), whereas *B. bengalensis* was more predominant in New Baligaon (67%) and Sorupatthar (51%). Share of *M. musculus* was 13-23%. The trap index and LBC are presented in Table 33

Table 33. Rodent incidence in poultry farms

Locations	**Species composition (%)**	**TI**	**LBC**	**Remarks**
Potiagaon	*B. bengalensis*(21) *R. rattus* (66) *M. musculus*(13)	8.62	26.6	Pucca foundation
New Baligaon	*B. bengalensis*(67) *R. rattus* (20) *M. musculus*(13)	14.67	46.2	Kaccha floor
Sorupathar	*B. bengalensis*(51) *R. rattus* (36) *M. musculus*(13)	12.21	28.8	Isolated area (distance from human habitat)
Nowboicha	*B. bengalensis*(21) *R. rattus* (56) *M. musculus*(23)	6.60	30.4	Near human habitat

Rodent management in Poultry farms: Two trials were undertaken on (i) on bromadiolone (0.005%) baiting and Ecodon (1:50) and (ii) rodenticides (acute and anticoagulant as solo as well as in combination along with Ecodon. After assessing pretreatment level of rodent infestation the burrows were treated with bromadiolone (0.005%) and ecodon (1:50). The results revealed that treatment of bromadiolone (0.005%) in poultry farms recorded 66.67 and 80.00% control success on 7^{th} and 10^{th} day of treatment respectively whereas the application of ecodon @ 1:50 yielded 73.33 and 82.22 % control success after 7^{th} and 10 th day of application respectively (Table 34).

Table 34. Effect of rodenticides and botanicals on the rodent incidence in the poultry farms

Treatment	Pre treatment Burrow count	Post treatment Burrow count		% Control success
		Live	Dead	
Bromadiolone (0.005%)	60			
7th Day		20	40	66.67
10th Day		12	48	80.00
Ecodon	45			
7th Day		12	33	73.33
10th Day		8	37	82.22

In the second trial, the pre and post treatment level of infestation was estimated by adopting the tracking index method. Bromadiolone baiting was done for 3 days where as zinc phosphide baiting was done for 24 hours after 2 days of pre baiting. The rodenticides treatments were applied during the end of the flock cycle. The Ecodon was applied 3 times at 15 days interval.

Table 34. Effect of different treatment on the reduction of rodent activity (% tracking index) in poultry farm

Treatment	Tracking index (%)			
	Pre control	Post control(DAT)		
		15	30	45
Bromadiolone+Ecodon	98.4	46.6(52.64)	32.2(67.22)	22.6(77.03)
Bromadiolone	96.2	48.8(47.27)	36.6(61.95)	33.3(65.38)
Zinc phosphide+Ecodon	92.2	32.2(66.87)	26.6(72.63)	20.2(79.21)
Zinc phosphide	94.4	36.6(61.22)	34.4(63.55)	40.6(56.99)
Ecodon	89.6	68.6(23.43)	40.2(55.13)	31.2(65.17)
Control	94.4	92.6	99.0	98.2

DAT-days after treatment. (Figures in the parenthesis indicate per cent reduction of rodent activity after treatments)

The data recorded on Table 35 reveals that average pre control per cent tracking index was 98.4 in case of bromadiolone + Ecodon treatment. During post treatment periods a reduction of 52.64 to 77.03 per cent tracking index was noticed due to bromadiolone baiting followed by application of botanical repellent (Ecodon) at 15 days interval. Whereas the single application of bromadiolone baiting reduced the rodent activity from 47.27- 65.38 %. The baiting of zinc phosphide in the poultry farm could reduce the rodent activity from 61.22 to 56.99 % whereas Ecodon was sprayed 3 times after zinc phosphide baiting gave a higher reduction in rodent activity *i. e* 66.87 to 79.21 %. The application of Ecodon in and around the

poultry farm reduced the rodent activity from 23.43 to 65.17%. From the trial, it can be concluded that the application of rodenticides have a good impact on reduction in rodent activity but considering the risk to the poultry birds, the rodenticides may be applied at the end of the flock cycle. The castor based rodenticides (ecodon) may be a good alternative to rodenticides in poultry sector.

4. FIELD EVALUATION OF DIFENCOUM AND FLOCOUMAFEN UNDER COMMENSAL SITUATIONS AS SPONSORED BY M/S BASF INDIA PVT LTD.

(a) DIFENCOUM (0.005%0 WAX BLOCK FORMULATION)

The rodenticide was evaluated under commensal situations (storage) for two seasons. First Season trials (during July - August, 2013) were conducted at two sites viz. village co-operative stores and grocery shops. Trapping in the study sites revealed moderate to heavy infestation of three rodent species viz., *R. rattus*, *B. bengalensis* and *M. musculus.* Ready to use wax block (each weighing 20 g) of Difenacoum (0.005%) were tested in both the trial sites along with a control (un-treated) for each site and the control success was measured by following two methods of census baiting and tracking. A sufficient numbers of bait stations (made of locally available hollow bamboo) were placed at an interval of 3m in order to cover the entire trial area. Powdered tracking tiles were placed nearby the bait points aligning the walls, about 1 meter away from the bait station.

The data presented in Table 35 a reduction of 56.55 – 79.83 per cent bait consumption as well as 29.52 – 78.30 per cent reduction of tracking index due to application of difenacoum (0.005%) in minimal baiting. The data recorded on site-II (village co-operative store) revealed higher rodent incidence than site-I (Grocery shops). Due to application of difenacoum (0.005%) in two pulses, the reduction of rodent activity in terms of census bait was 49.51 to 76.24 per cent and the reduction of tracking index, it was 39.60 to 81.80 per cent respectively at first and second pulsing, whereas in control the census bait consumption was 22.84 and 21.84 g and tracking index was 100 per cent in both the pulses, respectively (Table 35).

Table: 35. Bioefficacy of Difenacoum (0.500%) wax blocks against commensal rodents in storage during 2013 (Season-I).

		site I	Control	Site II	Control
Pre control	Census bait (g)	19.84	20.4	20.2	20.62
	Tracking index %	94.5	100	100	100
Mid control	Census bait (g)	8.62	18.8	10.2	22.84
	Tracking index %	66.6	96.6	60.4	100
Final control	Census bait (g)	4	18	4.8	21.84
	Tracking index %	20.5	90.2	18.2	100
Control success (%) 15 days after	Census bait (g)	56.55	0	49.51	0
	Tracking index %	29.52	0	39.6	0
Control success (%) 30 days after	Census bait (g)	79.83	0	76.24	0
	Tracking index %	78.3	0	81.8	0

The second season trial (November, 2013 to January, 2014) was also conducted at two sites viz. village co-operative stores and grocery shops with similar methodology. The data presented in Table 36 revealed that average pre-control bait consumption was 12.44 g, whereas the per cent tracking index was 82.40.The corresponding value in case of control was 12.02 g

and 84.60 per cent respectively. The data recorded on rodent activity at post treatment pulsing at site I showed a reduction of 40.51-77.17% bait consumption as well as 19.17-89.34 % reduction of tracking index due to application of difenacoum (0.005%) in minimal baiting (Table36). The data recorded on site-II also the reduction of rodent activity in terms of census bait ranged from 30.58-81.60% and reduction of tracking index ranged from 22.45-85.94% at different pulses whereas in control the census bait consumption it was 12.98 to 15.60 g and 86.90 to 90.42 per cent for respective parameters (Table 36).

Table 36. Bioefficacy of Difenacoum (0.500%) wax blocks against rodent pests in Storage during 2014 (Season-II).

Rodenticide	Census method	Pre-control	Reduction in relative activity		
			Post treatment		
			Pulse I	***Pulse II***	***Pulse III***
Site-I(Village grocery shops)					
Difenacoum	Bait consumed(g)	12.44	7.40 (40.51)	5.22 (58.03)	2.84 (77.17)
	Tracking Index (%)	82.40	66.60 (19.17)	34.40 (58.25)	8.60 (89.34)
Control	Bait consumed(g)	12.02	13.60	12.69	14.29
	Tracking Index (%)	84.60	86.00	84.29	87.60
Site-II: (village co-operative store)					
Difenacoum	Bait consumed(g)	16.42	11.40(30.58)	6.50(60.42)	3.02(81.60)
	Tracking Index (%)	88.22	68.42(22.45)	30.00(66.00)	12.40(85.94)
Control	Bait consumed(g)	14.96	12.98	13.00	15.60
	Tracking Index (%)	90.02	86.90	90.42	90.29

(Figures in the parenthesis indicate per cent reduction in relative activity at each pulse treatment)

(a) FLOCOUMAFEN (0.005%0 WAX BLOCK FORMULATION)

First Season Trials: The trial was conducted during July - August, 2013 at two sites viz. Village co-operative store and grocery shops. The rodent species were found to be *R. rattus, B. bengalensis* and *M. musculus.*

Ready to use wax block of flocoumafen 0.005% were tested in two seasons at both the trial sites along with a control (un-treated) area for each site following similar methodology as explained with difencoum trials.

The pretreatment data revealed 14.62 g bait consumption and 74.60 per cent tracking index in site I (grocery shop) whereas the corresponding data in case of control was 15.24 g and 76.66 per cent. The data recorded on rodent activity at post treatment after 1st ,2nd and 3rd pulse revealed a control success of 43.92-83.52 per cent on the basis of bait consumption and 24.12-85.79 per cent on the basis of tracking index due to application of flocoumafen in minimal baiting technique (Table 37). The data recorded on site II (village co-operative store)

revealed comparatively higher rodent incidence than site –I(grocery shops) . Due to application of anticoagulant rodenticides, the reduction of rodent activity in terms of census bait ranged from 44.54-85.92 % and reduction of tracking index ranged from 30.02-85.40 % in different pulses whereas in control during the treatment period the rodent activity in terms of bait consumption and tracking activity was almost uniform and infestation was heavy (Table 37).

Table 37. **Efficacy of Flocoumafen (0.005%) against commensal rodents in Storage during 2013 (Season-I).**

Rodenticide	**Census method**	**Pre-control**	**Reduction in relative activity**		
			Post treatment		
			Pulse I	***Pulse II***	***Pulse III***
Site-I (Village grocery shops)					
Flocoumafen	Bait consumed(g) Tracking Index (%)	14.62 74.60	8.20(43.92) 56.60(24.12)	6.54(55.27) 24.20(67.56)	2.41(83.52) 10.60(85.79)
Control	Bait consumed(g) Tracking Index (%)	15.24 76.66	14.46 78.42	16.60 74.21	15.10 79.20
Site-II: (village co-operative store)					
Flocoumafen	Bait consumed(g) Tracking Index (%)	18.40 86.60	10.26(44.54) 60.60(30.02)	6.50(64.33) 22.40(74.14)	2.69(85.92) 12.64(85.40)
Control	Bait consumed(g) Tracking Index (%)	20.66 87.49	18.42 90.06	20.82 89.60	20.40 90.49

(Figures in the parenthesis indicate per cent reduction in relative activity at each pulse treatment)

The second season trial was conducted during November, 2013 to January, 2014 again at two sites viz., village co-operative stores and grocery shops with similar methodology. The data recorded on rodent activity at post treatment after 1st ,2nd and 3rd pulse revealed a control success of 58.92 -95.95 per cent (bait consumption) and 40.11 to 97.24 per cent (tracking index) due to application of flocoumafen in minimal baiting technique (Table 38).

After application of anticoagulant rodenticides in the second season, the reduction of rodent activity in terms of census bait ranged from 48.83 – 81.25 % and reduction of tracking index ranged from 35.80 – 93.40% in different pulses whereas in control during the treatment period the rodent activity in terms of bait consumption and tracking activity was almost uniform and infestation was heavy (Table 38).

Table 38. Efficacy of Flocoumafen (0.005%) against commensal rodents in Storage during November, 2014 (Season-II).

Rodenticide	Census method	Pre-control	Reduction in relative activity		
			Post treatment		
			Pulse I	***Pulse II***	***Pulse III***
Site-I (grocery shops)					
Flocoumafen	Bait consumed(g) Tracking Index (%)	18.50 94.50	7.60(58.92) 56.60(40.11)	3.66(80.22) 18.00(80.95)	0.75(95.95) 2.60(97.24)
Control	Bait consumed(g) Tracking Index (%)	22.20 100.00	20.08 96.60	23.10 100.00	22.00 94.60
Site-II: (village co-operative store)					
Flocoumafen	Bait consumed(g) Tracking Index (%)	22.40 100.00	11.46(48.83) 64.20(35.80)	6.60(70.54) 20.20(79.80)	4.20(81.25) 6.60(93.40)
Control	Bait consumed(g) Tracking Index (%)	20.62 100.00	22.84 100.00	21.84 100.00	20.44 100.00

(Figures in the parenthesis indicate per cent reduction in relative activity at each pulse treatment)

EXTENSION ACTIVITIES

1. REFRESHER TRAINING ON RODENT PEST MANAGEMENT

A refresher training on rodent pest management was organized jointly by the AINP on Rodent Control, Department of Entomology,AAU,Jorhat in collaboration with National Institute of Plant Health Management(NIPHM),Hyderabad from March 10-16,2014 at the Directorate of Research (Agriculture), AAU, Jorhat. Altogether 20 participants in the rank of Agricultural Development Officer (ADO), SMS (KVK), and Assistant Professors attended the training programme from all North Eastern States. Dr G N Hazarika, DR (Agri.) who was the Chairman of the organizing Committee thanked NIPHM, Hyderabad for selecting the AAU as venue as part of their National Plan on Rodent Pest Management. A good number of officials from NIPHM, Hyderabad attended the said training programme as resource person. Dr D K Bora, Ex-PI and Director, Student Welfare, AAU, Jorhat, Br B C Dutta, Principal Scientist (Entomology),RARS, Titabor, Dr. R Borkatoki, Scientists(KVK) also acted as resource person. All the important aspects of rodent pest management was covered and due emphasis was given on field practical. The Training was successfully completed under the guidance of the Course Director, Dr R K Borah, Principal Investigator of the Project as well as Co Course Director, M Baruah.

2. Farmers Trainings

S.No.	Date	Topic	Venue
1	18.06.2012	Rodent pest management in rice field	36 Ghoria, Bekajan, Jorhat
2	10.07.2012	Rodent Pest management in state	Bhorolua, Kakajan, Jorhat
3	21.11.2013	Farmers Fair to exhibit different traps, bamboo traps, methods demonstration	Sugarcane Research Station, Buralikson, AAU
4	6.11.2013	Farmers Day	RARS, Titabor, AAU
5 6	19-07-2013	Interaction programme on squirrel damage assessment in coconut	Kordoiguri, Borpathar

7	23-08-2013	Interaction programme on rodent damage assessment in *Sali* rice	Bahuabeti, Nagaon
8	25-07-2013	Discussion on Rodent Pest Infestation in rice, vegetables etc.	Malowopathar, Jorhat
9	26-11-2014	Farmers Fair to exhibit different traps, local bamboo traps, methods demonstration etc.	Sugarcane Research Station, Buralikson,AAU
10	06-08-2014	Interaction programme on rodent infestation and their damage assessment in poultry farm	Patia gaon(Balijan),Jorhat
11	29-08-2014	Interaction programme on rodent damage assessment in *Sali* rice	Bahuabeti, Nagaon
12	12-08-2014	Discussion on Rodent Pest Infestation in rice- vegetables cropping system	Malowkhat, Jorhat
13	30-03-2014	Exhibited at Krishan Mela at KVK,Jorhat from Rodent Control	KVK, Jorhat

3. Field Demonstrations

Sl. No	Date	Topic	Venue
1	04.10.2012	Preparation of poison bait of Zinc phosphide and application in the rice field	Dergaon,Golaghat
2	06.11.2012	Identification of live burrows,bait station placement in the field	Bekajan, Jorhat
3	23-09-2013	Preparation of poison baits of zinc phosphide and their field application	Namoni Malowkhat Gogoi Gaon, Jorhat
4	15-09-2013	Preparation of poison baits of zinc phosphide and their field application	Namoni Malowkhat Gogoi Gaon, Jorhat
5	04-10-2013	Methods demonstration of local bamboo traps in *Sali* rice	Malowkhat, Jorhat
6	01-10-2013	Methods demonstration of different rodent management techniques	RARS: Titabor
7	22-01-2014	Demonstration of field application of local bamboo traps in vegetables	Balliatti, Gorumora
8	11-11-2014	Methods demonstration of local bamboo traps in *Sali* rice	Malowkhat, Jorhat
9	28-11-2014	Methods demonstration of different rodent management techniques	Jamuguri, Nowgaon

PUBLICATIONS

Borah, R. K. and Bora, D K. 2012. Incidence and damage of *Bandicota bengalensis* in rice based cropping system in Upper Brahmaputra Valley of assam *Ann.Pl.Protec.Sci.***20** (2):380-382.

Gogoi, P.P. and Borah, R. K. 2012. Burrowing behavior of lesser bandicoot rat, *Bandicota bengalensis* in rice ecosystem in Upper Brahmaputra valley of Assam*Ann.Pl.Protec.Sci.***20** (2):483-484.

Gogoi, P.P., Bora, D K, Bhattacharyya, B and Borah R K. 2013.Effect of Plant extract and insecticides on the immature stages of *Trichogramma chilonis* ishii. *Ann.Pl.Protec.Sci.* **21** (1):27-29.

Borah,R. K. and Saikia, S.2013.Evaluation of different bait additives against *Bandicota bengalensis* in rice field. *Ann Pl. Protec.Sci.***21***(1):98-100*

Borah, R. K. and Gogoi, P. P. 2013. Population fluctuation and incidence of *Bandicota bengalensis* in rice fields. *Ann Pl. Protec. Sci.* **21***(2):436-437*

Borah, R. K. and Bora, D. K .2013. Laboratory Evaluation of botanicals against *Rattus rattus* and *Bandicota bengalensis. Ann Pl. Protec. Sci.* **21***(2):437-439*

Gogoi, P. P and Borah, R. K. 2013. Incidence of lesser bandicoot rat, *Bandicota bengalensis* in rice ecosystem in the Upper Brahmaputra Valley. *Indian J Ent.* **75**(1):19-22.

Gogoi, P.P. and Borah, R.K. Burrowing behavior of lesser bandicoot rat, *B. bengalensis* in rice ecosystem in UBVZ of Assam, *Ann.Pl. Prtoec. Sci*. 20 (2): 464-509

Gogoi, P.P. Bora, P.K. Bhatta, B. and Borah, R.K. Effect of plant extract and insecticides on immature stage of *T. chilonis*, *Ann.Pl. Prtoc.Sci*. 21 (1): 27-29

Saikia, S and Borah, R. K.2013.Evaluation of rodenticides in the rice fields against *Bandicota bengalensis* in Assam. *Indian J Ent.* **75**(3):199-202.

Bora, D. K. and Borah, R. K. 2013.Incidence of rodent pests in rice-vegetables cropping systems in Assam. *Rodent Newsletter,* **37**:3-4.

Bora, D K, Borah, R K and Tripathi R S 2013. Rodent and their management in rice fields and households (Extension Bulletin), AINP on Rodent Control, AAU, Jorhat pp4

Borah, R K and Bora, D K. 2013. Dhan khetit endur Niyantranar Vybastha (Extension Bulletin) AINP on Rodent Control, AAU, Jorhat pp4

Bora, D K and Borah, R K. 2013. Rodent Pest Management. Training Mannual for Refresher Training on Rodent Pest Management

Baglari, D. and Borah, R. K. 2014.Evaluation of botanicals, traps and rodenticides against *Bandicota bengalensis* in rice ecosystem *Indian J Ent. , **76**(1):64-68.*

Borah, R.K. and Baglari, D.2014. Evaluation of traps against *Bandicota bengalensis* in rice field at the upper Brahmaputra valley zone of Assam. *Crop Res.* **48**(1,2&3):72-75(2014)

Saikia, S. and Borah, R. K..2014. Efficacy of rodenticides baiting in the rice fields at Upper Brahmaputra Valley Zone of Assam *Indian J Ent.* **76** (4):321-324.

Borah, R. K. and Dutta, B .C. 2014.Rodent management in poultry farms. *Rodent Newsletter,* **38**(1-4):8-10

Borah, R. K. and Bhattacharyya, B.2015.Toxicity of anticoagulant rodenticides against *Rattus rattus Ann. Pl. Protec. Sci.* **23**(1); 135-139.

Assam Agricultural University, Jorhat
Actual expenditure for the FY 2012-13 to 2014-15
(ICAR Share only)

(Rs. in lakhs)

Head/ Year	2012-13	2013-14	2014-15	Total
Pay & Allowances	41.75	41.46	49.10	**132.31**
T.A.	0.20	0.37	0.23	**0.80**
Rec. Contingencies	1.51	1.97	1.98	**5.46**
NRC	0.00	0.00	0.00	**0.00**
Total	**43.46**	**43.8**	**51.31**	**138.57**

Central Island Agricultural Research Institute
Port Blair (A&N Islands)-744 101

PART-I: GENERAL INFORMATION

1	Name of the center	Central Island Agricultural Research Institute, Port Blair (A&N Islands)-744 101
2	Name of Principal Investigator	Ms T. Bharathimeena, Scientist (Entomology)
3	Date of start	01.04.2009
4	Reporting period	April, 2012 to March, 2015

PART-II: WORK ALLOTTED

1. Surveillance and population ecology of rodent pests in predominant cropping systems
2. Monitoring the rodent abundance and damage in selected agro-climatic zones
3. Development and refinement of rodent pest management technologies in predominant crops/ cropping systems
4. Rodent management in vegetables and storage
5. Monitoring spread of *Bandicota bengalensis*
6. Collection and preservation of major field and storage rodent species of the region in laboratory
7. Field evaluation of Difencoum and flocoumafen in coconut
8. Transfer of rodent management technologies

PART III: WORK DONE

Andaman and Nicobar islands constitute a chain of 572 Islands located about 1200 km away from mainland in Bay of Bengal. The Islands stretch from North to South covering the longitude of 93°- 94° in East and the latitude of 6°– 17° of North. Main crops grown in Andaman and Nicobar Islands are rice, coconut, vegetables and fruit crops. Rice is the second most cultivable crop in Andaman and Nicobar Islands next to coconut. Pest and diseases plays major role in yield reduction. In the recent years, rodents also are emerging as serious pests of rice in the island conditions. Rodents are persistent pests in the island ecosystem. They plunder field crops, rice in particular and also cause severe damage to plantation crops and vegetables.

1. SURVEILLANCE AND POPULATION ECOLOGY OF RODENT PESTS IN PREDOMINANT CROPPING SYSTEMS

1.1. Rodent species diversity in Andaman and Nicobar Islands

A total of 19 rodent species has been recorded; they include one sciurid species and 18 murids. Genus *Rattus* is represented by 8 species and five sub species of *Rattus rattus*. Out of 19 species, three species (*Rattus palmarum, R. stoicus* and *R. burrus*) are endemic to these islands. Miller's long footed rat, *Rattus stoicus* and Zelebor's Nicobar rat, *R. palmarum* were major rodent species of Nicobar Islands. The House rat species include *Rattus rattus alexandrianus, R.r. and amanensis, R. r. atridorsum, R. r. flebilis* and *R. r. holochu*. Other *Rattus* species include *R. burrescens, R. burrulus, R. burrus, R. palmarum, R. pulliventer, R. rogersi, R.*

stoicus and *R. taciturnus.* Little Indian field mouse(*Mus booduga*), Asian house rat (*Rattus tanezumiandamanensis*) and cutch rock- rat, *Cremnomys cutchicus* were reported as new species from Andaman islands. *Mus musculus* were collected from household and rice fields of Andaman and *Bandicota bengalensis* were collected from paddy fields of Andaman. The collected specimens of *Mus booduga* (Gray) from Andaman were found to be of 9.3- 10.1 g weight with their tail shorter than the HB length. The average body weight of *R. Tenezumiandamens*is collected from Andaman was 137.1±39.79 g(107-230 g) with a naked, bicolour tail. Head-body length ranged between 157-178 mm (mean; 171.13± 6.81 mm).The cutch rock rat collected from Andaman were found to be HB length (182.5±23.11 mm)was longer than the tail (160.17±10.23 mm) with an average body weight of 128±28.8 g.

Miller's long footed rat, *Rattus stoicus* and Zelebor's Nicobar rat, *Rattus palmarum* and the Nonsense rat, *Rattus burrus* were the major rodent species from Nicobar. These three species are endemic to the islands. Out of twenty four specimens collected, eight were identified as *Rattus stoicus,* ten were identified as *Rattus palmarum* and 6 were identified as *Rattus burrus* by ZSI, Kolkata.

2. MONITORING THE RODENT ABUNDANCE AND DAMAGE IN SELECTED AGRO-CLIMATIC ZONES

2.1. Coconut

Rodent damage in coconut palms is obvious with certain characteristic symptoms. Rats gnaw the outer covering of the nut and make a small hole (about 5 cm diameter) near the perianth region. The damage dnut usually remains on the bunch for 2 to 6 days and finally they drop down. The fallen nuts with cut holes near perianth region are an important symptom of rat infestation in a plantation. The damage ranges from slight gnawing on small nuts to complete consumption of the meat inside the cavity of medium to large ones. The nuts are usually tunnelled into near the basal portion or about half way along the length of the pericarp or outer husk. The basal portion of the nut is more accessible to rats than the lateral or distal portions.

Survey was conducted in 8 different locations of South Andaman viz., Rangachang, Burmanallah, Kodiyaghat, Wimberlygunj, Bambooflat, Saithankhari, Collinpur, Chouldhari during months of August – September 2015. Among these locations coconut palms in Rangachang village recorded the highest per cent rodent infestation (25.00) and per cent nut damage(7.75) (Table 1). The infestation levels and nut damage was calculated using the formula;

$$\text{Percent rodent Infestation (RI)} = \frac{\text{No. of trees with fallen nuts}}{\text{Total No. of trees}} \times 100$$

Similarly, the nut damage was assessed by randomly selecting 10 trees with fallen nuts in the same orchards. The number of healthy and damaged nuts on the branches of selected trees was recorded. Rodent nut damage (percent) was calculated using the following formula:

$$\text{Nut damage (percent)} = \frac{\text{No. of damaged nuts}}{\text{Total number of nuts}} \times RI$$

Table 1. Rodent infestation and extent of nut damage in coconut in different locations in South Andamans

SN	Location	%Rodent Infestation	%Nut Damage
1	Rangachang	25.00	7.75
2	Kodiyaghat	13.15	3.33
3	Wimberlygunj	5.19	0.35
4	Collinpur	7.24	0.12
5	Burmanallah	5.88	0.093
6	Chouldhari	9.6	0.141
7	Bambooflat	5.55	0.045
8	Shaitankhari	12.5	0.374

In other islands like, Little Andamans, Neil and Haveloc, 5.64 to 65.23% trees were infested with rodents, the nut damage ranged from 4.16-5.88% only. Maximum trees (65.23%) were reported to be infested in Harminder Bay Village in Little Andaman Island, whereas Govindnagar (Havelock Island) island reported least (5.64%) infestation (Table 2).

Table 2. Rodent infestation in coconut in different locations and nut damage in Little Andamans, Neil Island and Havelock Island during 2011-12

Little Andamans			
SN	**Location**	**Rodent infestation (%)**	**Nut damage (%)**
1	Robindra Nagar	12.65	5.00
2	Vivekananda pur	23.50	4.76
3	Netaji Nagar	45.12	5.88
4	Ramakrishna Pur	23.50	5.00
5	Harminder Bay	65.23	5.88
Neil Island			
6	Village No: 4	12.31	5.00
7	Village No:3	25.60	5.00
8	Village No:1	12.53	5.00
Havelock Island			
9	Govind Nagar	5.64	4.42
10	Village No:3	15.33	4.16
11	Krishna Nagar	12.42	4.16

2.2. Rice

Rice being the second most cultivable crop is of primary agricultural importance in the Andaman and Nicobar islands. Rodents are emerging as serious pests of rice in North, South and Middle Andamans equivalent competition with other insect pests and crop diseases. Rodents damage rice crop in all the stages of growth. They cut and uproot newly transplanted seedlings. Tillers are diagonally cut normally 5-10 cm above the water level. The damage can be easily recognized when the tillers are thickened and possess hollow tubular cross section. Survey in paddy fields to document rodent infestation was conducted in 15 villages of South Andaman and 3 villages of North Andaman. Fifteen villages of South Andaman were selected for the study, were Guptapara, Mangultan, Wandoor, Calicut, Chouldhari, Ograbranch, Colinpur, Tirur, Tushnabad, Manpur, Ferrargunj, Mitakhadi, Shaitankhadi, Wimberligunj, Namunagar and 3 villages of North Andaman viz., Subash gram 1 & 2 and Keralapuram. Infestation levels ranged from 3.66 to 22.50 percent and hence the problem under study is of

crucial importance. The maximum rodent infestation was observed in Chouldhari, Subhash gram 1&2 and Colinpur village recorded minimum damage(Fig. 1 and Table 3).

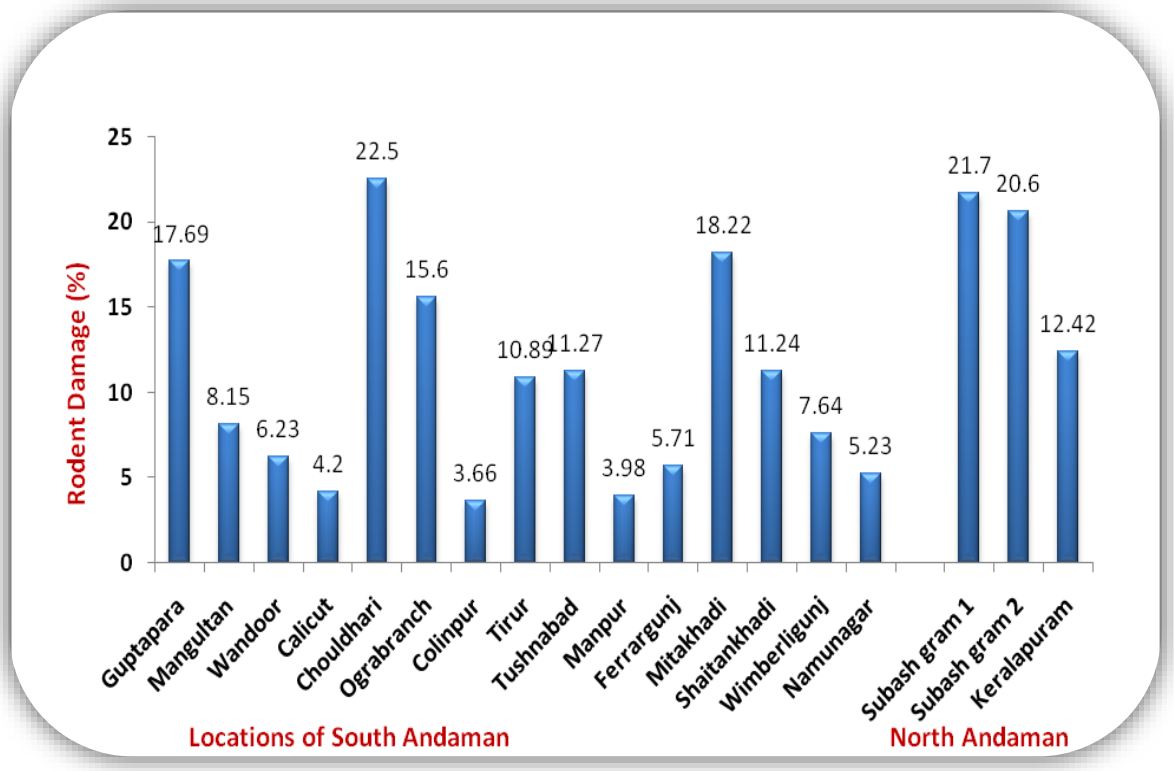


Fig.1. Rodent damage in rice in Andamans during 2013

Table. 3 Rodent infestation and damage in rice fields of Andamans

South Andaman		
1.	Guptapara	17.69
2.	Mangultan	8.15
3.	Wndoor	6.23
4.	Calicut	4.2
5.	Chouldari	22.5
6.	Ograbrach	15.6
7.	Colinpur	3.66
8.	Tirur	10.89
9.	Tushnabad	11.7
10.	Manpur	3.98
11.	Ferragunj	5.71
12.	Mittahadi	18.22
13.	Shaitanhadi	11.24
14.	Wimberilygunj	7.64
15.	Namunagar	5.23

North Andaman		
16.	Subhash gram 1	21.7
17.	Subhash gram 2	20.6
18.	Keralapuram	12.42

3. DEVELOPMENT AND REFINEMENT OF RODENT PEST MANAGEMENT TECHNOLOGIES IN PREDOMINANT CROPS/ CROPPING SYSTEMS

3.1. Rodent management in Coconut

A field experiment was carried out at South Andamans to evaluate the efficacy of control methods against rodents in coconut and also to find out the best and most suitable method which can reduce such losses. A trial was laid out in Randomized Block Design with four treatments replicated seven times including control. Among the treatments, **T_1**included use of crown baiting with of rodenticidal cake, bromadiolone(0.005percent), two cakes (30-35g) were placed on the crown of each palm, one on each side at the base of panicle bearing tender nuts, **T_2** included trunk banding with aluminium sheet, **T_3** was trunk banding with polythene sheet and **T_4**was untreated control. Percent control success was calculated using the following formula:

$$\% \text{ rodent control success} = \frac{A - B}{A} \times 100$$

A= RI of Pre-treatment

B= RI of Post-treatment

Basic observations were recorded before imposing the treatment and from then on monthly observations for fallen nuts were recorded. Estimation of losses on tender nuts was carried out based on unit count method. The data was subjected to statistical analysis following standard methods. The data in Fig. 4 revealed that crown baiting with bromadiolone cake (0.005 percent) was effective in reducing rodent damage from 85.70 to 28.57 per cent followed by trunk banding with aluminium sheet (71.42 to 42.85percent). In the present study, use of bromadiolone (0.005 percent) readymade rodenticide cakes to the palm crown was found more effective as its rodent control success was 66.66percent whereas in case of aluminium sheet and polythene sheet percent rodent control success was 40.0 and 33.33 per cent respectively. Crown baiting technique with bromadiolone does not require pre-baiting and is also cost effective.

3.2. Rodent Management in Rice

A trial was laid out in paddy fields of Subash Gram I, Subash Gram II and Keralapuram villages of North Andaman and Chouldhari village of South Andaman. Poison bait was prepared by the mixing of 960 g of broken rice, 20 g of oil and 20 g of zinc phosphide. Pre-baiting was done without the toxicant for two days and then 10 g poison bait was placed at the entrance. Observations were recorded on the quantity of bait consumed by the rats and the dead rat specimens were counted five days after treatment. On the first day all the burrows on the bunds

of rice field were closed. The following day the reopened burrows (live burrows) were identified, counted and pre-baiting was done without toxicant for two days and later 10 g poison bait packet @ 1 packet per burrow was placed on the third day. The following day observation was recorded on the quantity consumption of baits by rats. Dead rat specimens were also counted and five days after treatment, the residual live burrows were examined. A week afterwards, re-opened burrows were observed. The same procedure was repeated and success of rodent control was evaluated. Rodent damage showed a decline after the poison baiting in all the study villages. In Chouldhari, about 16 dead rats were observed after zinc phosphide treatment in the paddy fields whereas Kerala Puram, Subash Gram 1 & 2 recorded 8, 11, and 9 numbers respectively.

4. RODENT MANAGEMENT IN VEGETABLES AND STORAGE

4.1. Rodent damage in Vegetables

In case of vegetables viz, brinjal and tomato was recorded. In case of brinjal the damage ranged from 5.76 to 46.59 percent, whereas it was 8.26 to 33.8 percent in tomato. The survey data revealed the predominance of *Rattus* species followed by squirrel in South Andaman region.

4.2. Rodent damage in storage

Rats and mice wreak havoc in storage godowns as in fields and they damage more than they consume. Faecal pellets, animal hairs and urine stained grains of rice can cause serious health hazards besides critically hampering consumer preference. Studies were carried out to document different species of rodents damaging stored grains and other commodities. Three species, *viz., Rattus rattus, Mus musculus* and *Bandicota bengalensis* were observed as major pests of stored rice, animal feed and poultry feed. *Mus sp.* was the most frequently caught species in traps laid out, indicating its predominance as a pest of stored grains and/or feed. Nearly 10-50percent losses were recorded in storage grains.

5. POST NATAL DEVELOPMENT

5.1. *Rattus tanezumiandamanensis*

Post natal developmental observations were recorded for *Rattus tanezumiandamanensis*. A litter consisted of 3-9 pups (Fig. 2 and 3).A female rat which was trapped on 27.01.2015 gave birth to nine pups on 3.02.2015. The new born pups were reddish pink in colour. After few hours, the colour changed to a dull shade of pink. Squealing sounds were made by pups. On the second day onwards the ear patches and eye lobe darkened. Mother rat showed strong maternal instincts and was found to be guarding the pups very fiercely. Even with slight disturbance and the pups moving out of protective enclosure made by the mother with cotton, it was observed to be picking up the pups and replacing them back. The pups developed tiny whitish whiskers on the fourth day. The pup turned grey colour on seventh day whereas uniform hair growth only abort night after birth by the time which pups also showed active locomotion on the floor of the cage. They started climbing on the bars of the cage only after their eyes were fully opened on the 20^{th} day. One month old pups were found feeding on bread pieces in addition to nurturing by mother. The details of Biology and morphometric studies are presented in Table 4 and 5.

Fig.2. New born pups

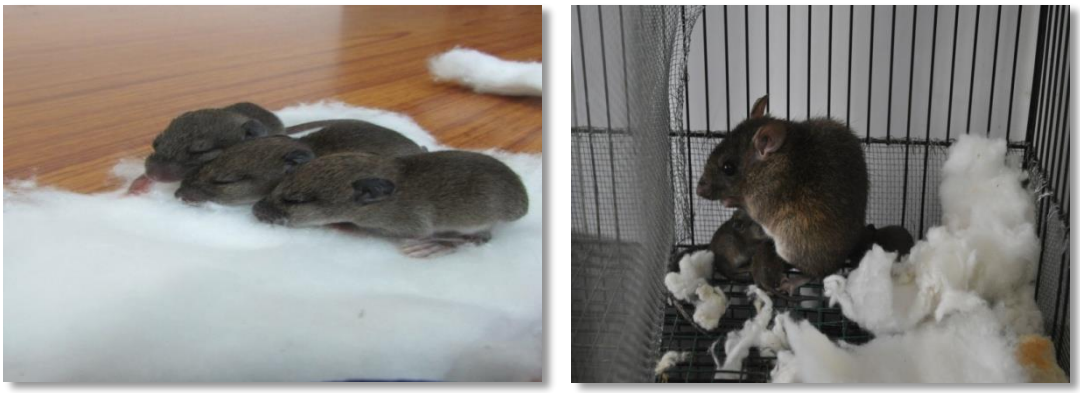


Fig.3. Post natal development

Table .4. Biology and morphometrics studies on *Rattus* sp.

Parameters	**Duration (days)**					
	8	**11**	**19**	**29**	**33**	**44**
Head length (mm)	1.16±0.05	2.68±0.06	2.96±0.12	NR	NR	NR
Body length (mm)	3.26±0.23	4.36±0.12	4.64±0.13	NR	NR	NR
Tail length (mm)	2.64±0.07	4.58±0.06	4.84±0.06	NR	NR	NR
Total body length (mm)	7.06±0.22	11.68±0.13	12.22±0.14	NR	NR	NR
Fore limb (mm)	NR	1.82±0.15	2.44±0.16	NR	NR	NR
Hind limb (mm)	NR	2.4±0.11	2.82±0.09	NR	NR	NR
Total body weight (g)	6.04±0.07	8.37±0.13	10.28±0.08	13.5±0.06	15.6±0.07	183.05±0.56

Table.5. Post- natal development of *Rattus* sp.

SN	Parameters	Duration (days)
1	Gestation Period	23
2	Date of darkening of ear lobe and eye patch	2
3	Thickening of skin and development of whiskers	4
4	Skin turning greyish pink and hair started developing all over body	7
5	Pups started moving slightly	11
6	Shiny black coloured hairs all over body and very activity feeding	15
7	Very active locomotion	17
8	Eye slightly opened	19
9	Eye fully opened	20
10	Weaning period	29

(i) Food consumption by *Rattus* sp. in laboratory: Laboratory experiments were simultaneously carried out to know the grain consumption per animal. *Rattus tanezumiandamensis*of uniform age was selected and the trapped rats were confined in cages for assessing grain loss by this species. It was found that on an average each animal consumed about 11.21 to 15.54 g of rice grains per day (Fig .4).

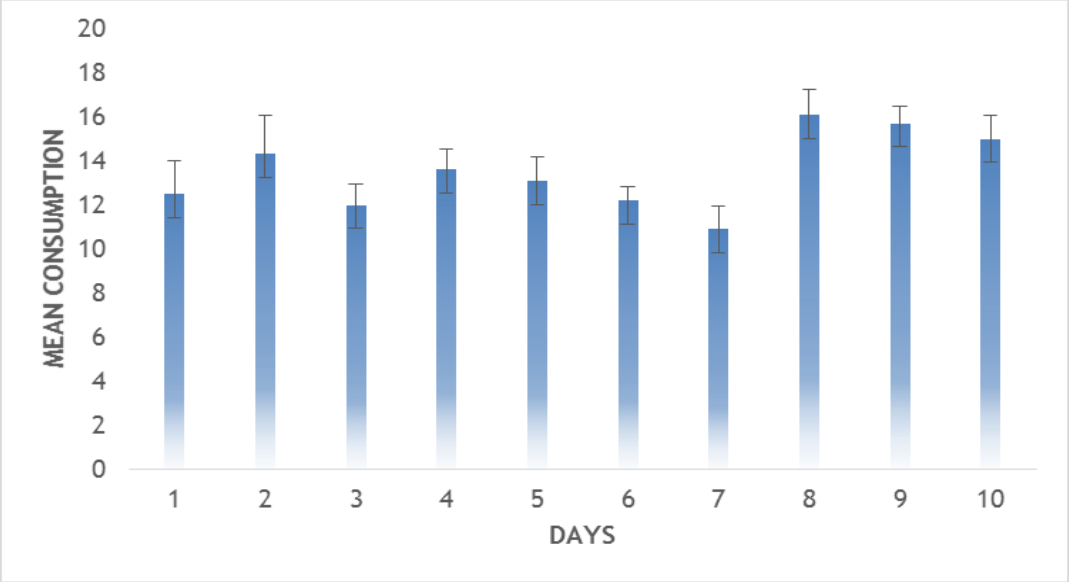


Fig.4. Mean daily food consumption by *Rattus* sp.

5.2. Monitoring spread of *Bandicota bengalensis*

(i) Collection of rodent specimen from rice fields: Traps were placed in experimental plots of rice fields. A Total of six specimens were collected from traps. All the six specimens collected from paddy fields of Andamans were identified as *Bandicota bengalensis* by ZSI, Kolkata. *B. bengalensis* was reported as new record from Andaman Islands and the specimen is being preserved in the institute laboratory. The lesser bandicoot rat or Indian mole rat (*B. bengalensis*) is a giant rat and is a threatening pest of cereals. It emits pig like grunts when attacking. The species is also a supposed threat to infants as a group of rats can easily attack

or even kill a lone victim. It is nocturnal and fossorial, constructs burrows with presence of scooped soil at the burrow openings. It is a robust species nearly (1kg). Head is round, muzzle broad and tail is shorter than head and body. Dorsum is dark brown in colour with coarse hairs. Favours embankments in and around rice cultivation.

6. COLLECTION AND PRESERVATION OF MAJOR FIELD AND STORAGE RODENT SPECIES OF THE REGION IN LABORATORY

All the species trapped from various locations in the Islands were identified by Zoological Survey of India, Kolkata and are preserved and maintained in the laboratory as are ference specimen. The species include; *B. bengalensis, Rattus rattus, R. palmarum, R. stoicus,* and *R. burrus, R. burrescens, R. burrulus, R. burrus, Mus musculus, M. booduga* and *Cremnomys cutchicus*.

7. FIELD EVALUATION OF DIFENCOUM AND FLOCOUMAFEN IN COCONUT

Two new rodenticides viz, difencoum and flocoumafen were evaluated in coconut orchards as part of sponsored trial from M/s BASF India Ltd during 2013-14. Studies on rodent infestation rate and nut damage in coconut plantations were undertaken at different locations of South Andaman district to evaluate the efficacy of two rodenticides namely the wax block formulations of **difenacoum**(0.005percent) and **flocoumafen** (0.005percent). Based on infestation levels, three villages namely Rangachang, Burmanallah and Calicut were selected as these locations recorded higher rodent infestation levels and the nut damage. A randomized block consisting of 100 trees was selected from each field and marked properly for each rodenticide. Around 20 per cent of the infested trees were selected for the evaluation of both rodenticides separately and 5percent of rodenticide treated tree was taken for assessment of nut damage. A control plot was maintained separately in each village. The control census was taken 15 and 30 days after pulsing. There was a drastic decline of rodent population and damage in all the three villages.

(i) DIFENCOUM: The trials were conducted in two seasons. During the first season the rodent infestation levels in Rangachang, Burmanallah and Calicut were 71percent, 78percent and 81percent, respectively and respective nut damage of 13.5, 27.51 and 19.5percent (Mean 20) respectively. In Difenacoum(0.5 percent) treated plots, rodent infestation rate was decreased drastically and the rodent control success after 15 days of pulsing were 84.5percent, 76.92percent and 83.95percent in three fields Rangachang, Burmanallah and Calicut, respectively (Mean: 81.79percent), while control success in nut damage was 95.71percent, 94.91percent and 97.59percent, respectively (Mean: 96.07percent) (Table 6).

During second season trial, field survey was undertaken as mentioned earlier for high rodent infestation and nut damage and three locations were selected ie., Calicut 1, Calicut 2 and MaccaPahad. The results revealed that in Difenacoum(0.500percent) treated plots, rodent infestation rate was decreased significantly and the rodent control success after 15 days of pulsing was 70.45, 45.58 and 56.94percent in three fields Calicut-1, Calicut-2 and Macca Pahad, respectively (Mean: 57.66percent), whereas control success in nut damage was 87.47, 67.01 and 72.87percent in respective sites with a mean success of 75.78percent (Table 3). The average rodent control success in infestation and nut damage in

difenacoum(0.500percent) treated plots after 30 days pulsing was reduced to 37.02 and 55.87percent, respectively.

Table 6: Evaluation of Difenacoum(0.005percent) wax blocks in Coconut plantation

Period	Parameters	Season I (April 2013		Season II (September 2013)	
		Mean of 3 treatment Villages	Control village	Mean of 3 treatment Villages	Control village
Pre control	Rate of infestation	76.6	73.5	76	74
	Nut damage (percent)	20	19.6	18.95	18.3
Mid control	rate of infestation	14	75.2	31.3	71
	Nut damage (percent)	0.81	19.1	4.14	18.1
Final control	Rate of infestation	21	72.4	46.67	72
	Nut damage (percent)	1.68	21.2	7.95	19.1
Control success after I pulsing (percent)	Rate of infestation	81.79	0	57.66	0
	Nut damage reduction	96.07	2.5	75.78	0
Control success after II pulsing (percent)	Rate of infestation	72.35	1.5	37.02	0
	Nut damage reduction	91.03	0	55.87	0

(i) FLOCOUMAFEN:

Studies on rodent infestation rate and nut damage on coconut plantations were undertaken in two seasons at different locations of South Andaman district to evaluate the bio-efficacy of Flocoumafen (0.005percent) following similar methods as mentioned above in difencoum trials.

The first season trial was undertaken in three villages namely Rangachang, Burmanallah and Calicut with high rodent infestation of about 71percent, 78percent and 81percent, respectively (Mean: 76.6percent) and with the nut damage of 12.81 to 27.51 percent (Mean: 13.82percent). The data showed in Table 4revealed that the rodent infestation and nut damage were significantly decreased in all the three villages in the treatments when compared to control. In Flocumafen (0.005percent) treated plots, rodent infestation rate, decreased and the rodent control success after 15 days of pulsing were 97.18percent, 89.74percent and 96.29percent in three fields Rangachang, Burmanallah and Calicut, respectively (Mean: 94.4percent), whereas the final control success was recorded as 99.21, 99.23 and 99.06 per cent respectively with a mean of 99.16 per cent. In control area untreated with flocoumafen, the nut damage was recorded as 18.8 and 17.6 respectively, while in treated blocks, the damage was nil in the orchards.

The second season trial was undertaken at three locations ie., Calicut 1, Calicut 2 and Macca Pahad. The rate of rodent infested trees ranged from 72 to 88(mean 76) with a nut damage ranging from 11.49 to 21.3 (mean: 16.66). The rate of infested trees came

down to 31 to 38 (Mean: 31.33percent) and nut damage to 6.16 to 7.02percent (mean 6.65). In Flocoumafen (0.005percent) treated plots, rodent infestation rate decreased drastically and the rodent control success after 15 days of pulsing at 80.68percent, 83.82percent and 77.77percent levels (mean: 80.76)while control success on nut damage basis was 88.89percent, 65.36percent and 87.68percent, respectively (mean: 80.64). The average rate of infestation and nut damage incidence in flocoumafen (0.005percent) treated plots after 30 days pulsing was recorded as 58.99percent and 56.83percent based on respective parameters (Table 7).

Table 7: Evaluation of Flocumafen(0.005percent) wax cake in Coconut plantation

Period	Parameters	Season I (April 2013		Season II (September 2013)	
		Mean of 3 treatment Villages	Control village	Mean of 3 treatment Villages	Control village
Pre control	Rate of infestation	76.6	73.5	76.00	74
	Nut damage (percent)	13.82	18.8	16.66	18.3
Mid control	rate of infestation	3.66	71.9	14.67	71
	Nut damage (percent)	0	17.6	2.82	18.1
Final control	Rate of infestation	13.3	73.8	31.33	72
	Nut damage (percent)	0.11	17.3	6.65	19.1
Control success after I pulsing (percent)	Rate of infestation	94.4	0	80.76	0
	Nut damage reduction	100	6.38	80.64	0
Control success after II pulsing (percent)	Rate of infestation	82.55	0	58.99	0
	Nut damage reduction	99.16	7.9	56.83	0

8. TRANSFER OF RODENT MANAGEMENT TECHNOLOGIES

8.1. Rodent management trainings

To create awareness, training and demonstration programmes were organised by All India Network Project on Vertebrate Pest Management and Out Reach Centre, Diglipur with the support of NABARD in different villages of Diglipur.

The First day training was conducted in R.K.Gram in Pradhan's office. The programme was inaugurated by Dr. R. K. Gautam, Head, Field Crops Division at CIARI, Port Blair. The manager, NABARD also participated in the programme where R.K. Gram village farmers learnt rodent pest management techniques to be adopted in rice. A total of 25 farmers participated in this training programme**(**Fig.5).

On the second day, two more training programmes were conducted in individual locations one at Keralapuram, Outreach Centre and the other at Youth club, Diglipur. A total

of 56 farmers participated in this programme. All the participants were keenly interested to learn the techniques of rodent management in rice fields.

On the third day, another training programme and field demonstration was conducted Subhashgram village. A total of 44 farmers mainly rice growers participated in this training programme. On the same afternoon, one another training programme was conducted at Madhupur village where about 44 farmers participated. Thus in all the four programmes 167 farmers including 56 women were benefitted (Table 8).

ORC at Keralapuram village NABARD Manager with our teams at R. K. Gram
Fig.5. Farmers' Training on Rodent Management

Table. 8. Details of training programme on Rodent pest management

Villages	Farmers Men	Farmers Women	Total
R.K.Gram	17	8	25
Keralapuram	42	14	56
Subhash Gram	28	16	44
Madhupur	24	18	42
Total	**111**	**56**	**167**

8.2. SUCCESS STORY OF RODENT CONTROL IN RICE

A survey was conducted by September 2013 in North Andamans and three villages with severe rodent infestation were identified to conduct field experiment to evaluate the efficacy of two rodenticides *viz.*,Bromadiolone cake (0.005percent) and zinc phosphide (2percent).The experiment was conducted in the panicle initiation stage of rice crop which is most prone to rodent attack. Live burrows were identified prior to application of treatments.

When applying zinc phosphide, two steps were followed *viz.*, pre-baiting and poison-baiting. Pre-baiting was done without toxicant for two days, and later on 10 g poison bait packet @ 1 packet per burrow was placed on the third day. Poison bait was prepared by the mixing of 960 g of broken rice with 20 g oil and 20 g of Zinc phosphide. Poison baiting was repeated in some fields where rodent activity was high. Observations on dead rats and reduced damage levels were recorded throughout the crop growth period.

Rodent control success was calculated using the formula C-T/C x 100 where C is the control data and T is the treatment data. The results of the experiments revealed that zinc phosphide was highly effective when compared bromadiolone cake.

While conducting experiments, farmers were taught to use rodenticides, with stern emphasis on the safety measures to be followed during the application of zinc phosphide and its toxicity to domestic animals and human beings. In addition, four training programmes were conducted to train farmers and rural youths through local youth clubs. Zinc phosphide was supplied to the needy farmers after clearly training them the safety measures to be adopted.

Mr Kamal and Mr Shri Sukantho Bepari , residents of Subash Gram village informed that they could get 8 bags of paddy in one bigha (0.29 ha)whereas only 6 bags could be procured in the previous year with severe rodent infestation. He also added that he could save the long duration paddy crop C14-8 for at least 8 months from Jun-Jul to Jan-Feb when they practiced applying zinc phosphide. The farmers showed enthusiasm in disseminating the technology among their friends and relatives in the farming community. This success story has inspired several other farmers who are willingly requesting for training programmes and supply of rodenticides. Recently zinc phosphide is being made available in 5 g and 10 g sachets in retail shops.

PUBLICATIONS

Research Papers

Birah, A., Kumar, A. S. and Tripathi, R.S. 2012. Status of rodent damage to coconut in Andaman and Nicobar Islands. *Journal of Plantation Crops* 40(3): 238-242.

Birah, A., Tripathi, R.S. and Mohan Rao, A.M.K. 2012. New report of little Indian field mouse, *Mus booduga* (Gray) from Andaman and Nicobar islands. *Journal of Plantation Crops* 40(2): 149-151.

Birah, Zamir Ahmad, S.K., Anantharaj, A., Tripathi, R.S. and Dam Roy, S. 2014. Occurrence of bandicoot rat, *Bandicota bengalensis* in paddy fields of Bay Islands, India. *Ann. Pl. Protec.Sci*.22 (1): 213-14

Birah, A. Anantharaj A. and Tripathi R. S. 2012. Rodent Diversity of Andaman and Nicobar Islands. *Sovenie*r *National Seminar on Innovative technologies for Conservation and Sustainable Utilization of Island Biodiversity*, December 20-22, 2012, Port Blair, p52-56.

Birah, A., Ahmad, Z., and Tripathi, R.S. 2013. *Dhan ki fasal mein Chooha Niyantran. Kheti.* September 2013: 32.

Sakthivel. K., Birah, A., Tripathi, R.S., Gautam. R.K., Singh, P.K., Ahmed, Z., Singh, A.K., Rao, S. S. and Dam Roy, S. 2015. Rodent menace and its management in Diglipur, North Andaman - a success story. Journal of the Andaman Science Association. 20(1): 63-65

Popular articles

Birah, A., Zamir, S.K., Tripathi, R.S. 2013. Dhan ke fasal mein chuha niyantaran, *Kheti.* September. 2013. pp. 32

Sakthivel, K., Bharathimeena, T., Gautam, R. K. and Dam Roy, S. 2014. Rodent Management Approaches in Paddy Fields and Grain Storage Conditions. *The Daily Telegram* (12th July 2014).

Radio talks

Talk delivered by Dr. R.K. Gautam, on topic "*Dhan ki fasal mein chuha niyantran"* . All India Radio, Port Blair (Broadcasted on 14-10-2014).

Central Island Agricultural Research Institute, Port Blair

Actual expenditure for the FY 2012-13 to 2014-15
(ICAR Share only)

(Rs. in lakhs)

Head/ Year	2012-13	2013-14	2014-15	Total
Pay & Allowances	0.00	0.00	0.00	**0.00**
T.A.	0.09	0.53	0.67	**1.29**
Rec. Contingencies	1.41	1.56	1.37	**4.34**
NRC	0.00	0.00	0.00	**0.00**
Total	**1.50**	**2.09**	**2.04**	**5.63**

COLLEGE OF HORTICULTURE & FORESTRY
CENTRAL AGRICULTURAL UNIVERSITYT, PASIGHAT-791 102

PART-I: GENERAL INFORMATION

1	Name of the center	College of Horticulture and Forestry, Central Agricultural University, Pasighat-791102, Arunachal Pradesh
2	Name of Principal Investigator	Dr. M. M. Kumawat, Assistant Professor
3	Name of Co- P.I.	(i) Mr. Siddhartha Singh, Asstt Professor, CHF, CAU, Pasighat and (ii) Mr. Toge Riba, Subject Matter Specialist, KVK, District East Siang, Arunachal Pradesh
4	Date of start	01.04.2009
5	Reporting period	April, 2012 to March, 2015

PART-II: WORK ALLOTTED

1. Surveillance of rodent pest rodents in predominant cropping systems.

2. Monitoring of rodent abundance and damage in selected agro-climatic zones of the region.

3. Development of integrated rodent management modules for different cropping systems.

4. Development of rodent management technologies under storage conditions.

5. Social engineering activity on rodent pests management as participatory adaptive research in adopted villages.

6. Studies on predatory potential of barn owls and its utilization for bio control of rodent pests.

7. Collection of rodent species and development of rodent museum.

8. Monitoring of spread of *Bandicota bengalensis* in Arunachal Pradesh.

PART-II: WORK DONE

1. SURVEILLANCE OF RODENT PESTS IN PREDOMINANT CROPPING SYSTEMS

During 2012-13, the survey of rodent pests infesting crop fields was carried out in East Siang, West Siang, Lower Dibang valley and Lohit districts of Arunachal Pradesh. The rainfed crops in this region harboured the population of *Rattus rattus, Rattus sikkimensis* followed by *Bandicota bengalensis*. The predominating cropping system was based on rice. Live burrow count (LBC), trapping index (TI) and rodent damage (per cent cut tillers) were recorded at tillering, flowering and ripening stages of Jhum and WRC system. The data revealed that live burrow count, trapping index and rodent damage at different crop stages increased with the advancement of the crop. Highest LBC (10.25), trap index (4.75) and cut tillers (2.22) were

recorded at ripening stage of the crop. LBC, TI and damage in maize crop were 5.50, 3.67 and 7.87%, respectively in the region. Likewise in vegetable crops the highest LBC was recorded on potato followed by pea, French bean and cowpea in Jhampani village. The highest per cent damage was recorded in cowpea (4.30%) followed by potato (2.40%) and pumpkin (1.25%) whereas in cauliflower, cabbage, carrot, radish and French bean, the damage was between 0.50 to 2.10%. The predominating species were *B. bengalensis, R. rattus* and *R. sikkimensis.* In pineapple, LBC/ha was 2.80 to 5.33 observed in different fields with damage percent from 1.50 to 8.87 in the region.

During 2013-14 number of live burrows/ha., trap index and damage in the month of June were less as compared to the harvesting stage of rice crop. The number of live burrows ha^{-1} increased subsequently and reached maximum in October and remained high in November to December. The mean number of live burrows ha^{-1} in crop season was ranged from 3.33 to 11.33 in the region. The trap index was ranged from 1.16 to 15.84 in all three districts. The damage percent in East Siang, West Siang and Upper Siang districts were ranged from 1.15 to 6.47, 0.82 to 2.89 and 0.74 to 3.01 respectively. In case of *Jhum* rice which is grown on the onset of *mansoon* the number of rodent population were less but it was gradually increased month by month. According to damage caused by rodents in rice crop, it is revealed that the highest damage was caused in East Siang district of Arunachal Pradesh then to other districts. Surveillance of rodent was also recorded on maize crop in the three districts of Arunachal Pradesh. The highest damage (6.78%) in maize was observed in Runne village of East Siang district followed by Tekkang village (5.59). The damage percent in West and Upper Siang districts was comparatively lower then to East Siang. The trap index and LBC ha^{-1} were found highest in East Siang district. Among the horticultural crops, highest damage (3.05 %) was observed in potato crop in all the villages ranged from 0.66 to 3.05%. the damage percent in cucurbits in different villages was ranged from 0.00 to 2.20%. In brinjal crop the damage was observed only in Oyan (0.40%) and Ranni (0.10%) villages, whereas no any damage symptoms was observed in other location. The maximum number of live burrows ha^{-1} (2.33) was observed in 12 Mile village whereas the maximum trap index was recorded in Sika Tode (14.87) followed by jampani (12.33).

Trap index, live burrow count (No./ha), extent of damage and reproductive status of the species were recorded in wet land rice, *Jhum* rice, maize, potato, tomato, cabbage, bean, brinjal and cucurbits in the surveys conducted during April, 2014 to March, 2015 in different villages of East Siang, West Siang and Upper Siang Districts and in the instructional and research farm, College of Horticulture and Forestry, Pasighat. In rice cultivation system, the number of live burrows/ha., trap index and damage in the month of June were less as compared to the harvesting stage of the crop. The LBC ha^{-1} increased subsequently and reached maximum in October and remained high in November to December. The mean number of live burrows ha^{-1} in crop season was ranged from 1.50 to 9.75 in the region. The trap index was ranged from 1.10 to 10.25 in all three districts. The average damage percent in East Siang, West Siang and Upper Siang districts were 2.05, 1.28 and 0.89, respectively. In case of *Jhum* rice which is grown on the onset of *mansoon* the number of rodent population were less but it was gradually increased month by month. According to damage caused by rodents in rice crop, it is revealed that the highest damage was caused in East Siang district of Arunachal Pradesh then to other districts. Surveillance of rodent was also recorded on maize crop in the three districts of

Arunachal Pradesh. The highest damage (4.25%) in maize was observed in Runne village of East Siang district followed by Tekkang village (2.62). The average damage percent in maize crop in East Siang, West Siang and Upper Siang districts were 1.65, 0.72 and 0.84, respectively. The damage percent in West and Upper Siang districts was comparatively lower then to East Siang. The trap index and LBC ha^{-1} were found highest in Upper Siang district. Among the horticultural crops, highest damage (2.67 %) was observed in cucurbits crop in all the villages ranged from 0.33 to 2.67%. The damage percent in potato in different villages was ranged from 0.28 to 2.56%. In brinjal crop the no any damage was observed in all the villages. The maximum number of live burrows ha^{-1} (1.67) was observed in 12 Mile village whereas the maximum trap index was recorded in Sika Tode (10.33) followed by Sika Bamin (7.87).

2. MONITORING OF RODENT ABUNDANCE AND DAMAGE IN SELECTED AGRO-CLIMATIC ZONES OF THE REGION.

During the monitoring, a total 156 rodents were trapped in East Siang Districts during 2013-14, out of which maximum trapping was found in cabbage (31) followed by beans (27), Jhum rice (24) and WRC (20). The highest trap index was recorded in jhum rice (9.25) followed by potato (6.67) and WRC (5.67) and maize (4.67). The average sex ratio (M:F) was found 1:0.90 in the rodent population of the district. *Rattus rattus* was relatively more abundant species of rodents in East Siang district. The relative per cent abundance of *R. rattus* was 64.74 followed by *R. sikkimensis* (15.38), *Mus cookiinagarum* (14.10) and *Bandicota bengalensis* (5.77). In West Siang Districts, a total 185 rodents were trapped out of which maximum trapping was found in WRC (37) followed by jhum rice (32), potato (24) and cabbage (22). The highest trap index was recorded in jhum rice (8.52) followed by WRC (7.04), beans (5.00) and potato (4.33). The average sex ratio (M:F) was found 1:0.77 in the rodent population of the West Siang district. *Rattus rattus* was relatively more abundant species of rodents in West Siang district. The relative per cent abundance of *R. rattus* was 72.97 followed by *R. sikkimensis* (16.22), *B. bengalensis* (6.49) and *M. cookiinagarum* (4.3). The bimonthly trap index was recorded for all the cropping systems prevalent in the region (Fig 1 and 2).

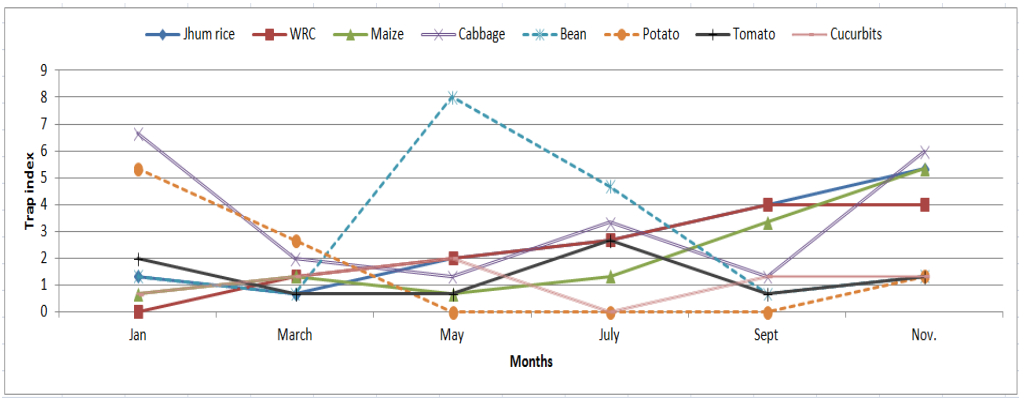


Fig. 1 Bimonthly trap index for different crops in East Siang District of Arunachal Pradesh

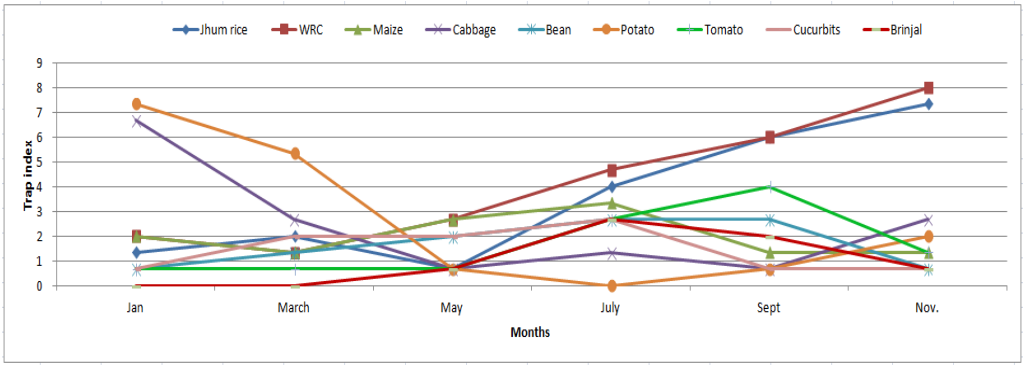


Fig. 2 Bimonthly trap index for different crops in West Siang District of Arunachal Pradesh

During 2014-15, a total 124 rodents were trapped in East Siang Districts, out of which maximum trapping was found in potato (26) followed by beans (21), Jhum rice (20) and WRC (15). The highest trap index was recorded in potato crop (8.67) followed by beans (7.00), jhum rice (6.67) and WRC (5.00). The average sex ratio (M: F) was found 1:1.05 in the rodent population of the district. *Rattus rattus* was relatively more abundant species of rodents in East Siang district. The relative per cent abundance of *R. rattus* was 52.94 followed by *R. sikkimensis* (22.65), *Bandicota bengalensis* (21.16) and *Mus cookiinagarum* (3.25). The bimonthly trap index was recorded for all the cropping systems prevalent in the region. In West Siang Districts, a total 91 rodents were trapped out of which maximum trapping was found in potato crop (18) followed by jhum rice (15), WRC (13) and cucurbits (10). The highest trap index was recorded in potato crop (6.00) followed by jhum rice (5.00), WRC (4.33) and cabbage (3.00). The average sex ratio (M:F) was found 1:1.20 in the rodent population of the West Siang district. *Rattus rattus* was relatively more abundant species of rodents in West Siang district. The relative per cent abundance of *R. rattus* was 51.32 followed by *R. sikkimensis* (29.27), *B. bengalensis* (15.60) and *M. cookiinagarum* (3.81). The relative abundance of rodents in East and West Siang Districts of Arunachal Pradesh is given in the fig 3 and 4.

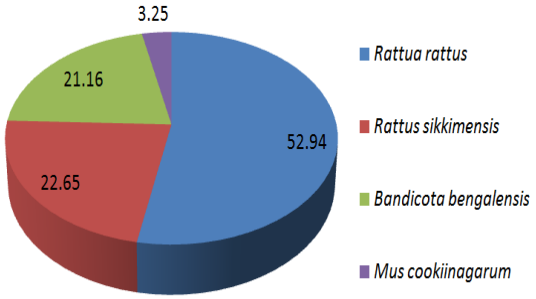


Fig. 3 Relative abundance (%) of rodent species in East Siang District of Arunachal Pradesh

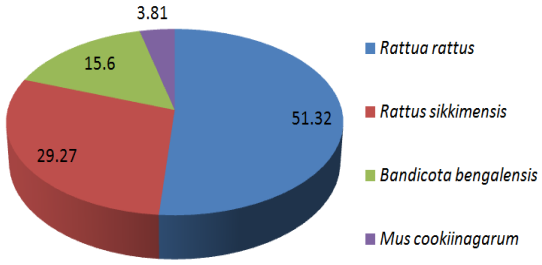


Fig. 4 Relative abundance (%) of rodent species in West Siang District of Arunachal Pradesh

3. SOCIAL ENGINEERING ACTIVITY ON RODENT CONTROL

During 2012-13, the site for social engineering activity was selected at Napit, Sikbamin and Jampani villages in East Siang district of Arunachal Pradesh. In adopted village (Sikabamin), trainings, demonstration of techniques and inputs were provided to farmers, whereas in partially adopted village (Napit), only training were provided to farmers without giving any inputs from the project. The major cropping system in adopted village was rice based only. In control village (Jhampani), no inputs or training were provided to farmers and data on rodent infestation was recorded. The training on rodent control was provided in the beginning of the crop season. The farmers of adopted village used installation of local traps from transplanting to harvesting stage of the crop, application of zinc phosphide at panicle initiation and dough stage of the crop.

Rodent infestation was increased gradually from tillering stage and reached upto peak at harvesting stage of the crop. In the adopted fields, rodent infestation decreased from panicle initiation stage of the crop. The per cent cut tillers in adopted village at PI stage was 4.20% which increased upto 6.24% in harvesting stage, while in control village the per cent cut tillers was 8.25% which increased up to 12.50% at harvesting stage.

KAP analysis: The questionnaire consisted of 55 questions as provided by PC cell, Jodhpur and information were collected accordingly under the head of (i) General information, (ii) Knowledge, (iii) Attitude and (iv) Practices. The trainings, demonstration and inputs were supplied in adopted village whereas in partially adopted village only training is conducted. No inputs and training was given in control village. Survey indicate that 98% of the population was depends upon the agriculture for their livelihood. The crop grown were rice, maize, vegetable and pineapple. Before intervention of AINP-RC in adopted village (Sikabamin), most of the farmers depend upon installation of local traps '*etku'* in the crop fields for the control of rodents. After intervention, 96% farmers of adopted village reported to use of zinc phosphide for the management. Most of the farmers (75%) did weed management on bunds and cut the grasses near fields. In partially adopted village (Napit), 85% farmers used to trap the rodents by installing local trap but none of the farmer used any chemical for management practices. Some of the farmers (30%) clean the weeds in their fields. Further, in control village (Jhampani), none of the farmer used chemicals although some farmers (60%) trapped the rodents by installing local trap.

During 2013-14, the community level rodent control programme under social engineering acivities was continued in three villages. The rodent campaign was organized in the month of July, September and October, 2013. Two villages namely Napit and Balek were selected as adopted and partially adopted villages respectively. Another village namely Taki Lalung was kept as control village. In adopted village (Napit) both training, method demonstration as well as inputs were supplied whereas in case of partially adopted village (Balek) only training was provided. The major cropping system of the adopted villages was Rice. In the beginning of the *mansoon* season of 2013 initial rodent population and damage index from the villages were recorded. Then in the village Napit, rodent control measures along with training on rodent pest management were provided. All the villagers participated in the training programme. In the control village, no inputs or training was provided and only data on rodent infestation were recorded. The rodent damage and population was recorded at the

beginning of the crop season followed by maximum tillering stage, panicle initiation stage and ripening stage of the crop. Before interventions of social engineering, the LBC ha^{-1}, trap index and rodent damage were recorded to compare the next year data i.e. after interventions of social engineering, trainings and knowledge.

The data indicated that rodent infestation increased gradually from tillering stage and reached a peak during the harvesting stage of the crop. Before adoption of the villages, rodent infestation increased from PI stage of the crop. After interventions, the LBC per hectare was also increased from tillering stage to harvesting stage. In the adopted village LBC was 2.20 in tillering stage and increased up to 5.40 in ripenning stage and then decreased again to 4.60 at harvesting due to intervention in terms of application of rodenticides (Zinc phosphide and Bromadiolone baiting. Similar trends were also observed in case of Trap Index and Cut tillers damage. Survey indicated that more than 78 % of the population was pure agriculturists while less than 22% had other livelihood also mainly services and small scale businessman. The cropping system was based on rice only. Similar trends were also observed in case of Trap Index and Cut tillers damage. The data on Practices of KAP analysis of the three villages are presented in table1. The programme was continued during 2014-15 also in the three villages, viz., Napit, Balek and TakiLalung in East siang district. The rodent campaign was organized in the month of August, October and November, 2014. Survey indicated that 68.70 % of the population was pure agriculturists while 31.30% had other livelihood also including services and small scale business.

Table 1. KAP analysis report about practices (2013-14)

Particulars	Per cent respondents		
	Napit	Balek	TakiLalung
Practices			
1. Weed management			
Yes	92.8	87.5	45.4
No	7.14	12.5	54.6
2. Repairing infested bunds			
Yes	100	100	68.18
No	0	0	31.82
3. Management in stores			
a) Metallic	0	0	0
b) Cleanliness	35.7	12.5	95.6
c) Rodent proofing	64.3	87.5	4.54
4. Washing trap			
Yes	0	0	0
No	100	100	100
5. Kill predators			

a) Kill	28.6	18.75	45.5
b) Not kill	71.4	81.25	54.5
6. Rodenticide use			
a) Not used	71.4	68.75	100
b) Zinc phosphide	14.3	18.75	0
c) Bromadiolone	14.3	12.5	0
7. Rodenticide use			
a) In burrow	7.14	31.25	0
b) Out side	21.4	0	0
c) Not used	71.4	68.75	100

Two villages namely Balek and TakiLalung were selected as adopted and partially adopted villages respectively. Another village namely Oyan was kept as control village. In adopted village (Balek) training, method demonstrations as well as inputs were supplied whereas in case of partially adopted village (TakiLalung) only training was provided. The major cropping system of the adopted villages was Rice. In the beginning of the *mansoon* season of 2014 initial rodent population and damage index from the villages were recorded. In Balek village, rodent control inputs along with training on rodent pest management were provided. All the villagers participated in the training programme. In the control village, no inputs or training was provided and only data on rodent infestation were recorded. In the beginning of the crop season, the farmers adopted the rodent control measures like, installation of local traps at PI stage and destruction of burrows. The rodent damage and population was recorded at the beginning of the crop season followed by maximum tillering stage, panicle initiation stage and ripening stage of the crop (Table 2). Before interventions of social engineering, the LBC ha^{-1}, trap index and rodent damage were recorded to compare the next year data i.e. after interventions of social engineering, trainings and knowledge (Table 2).

The data indicated that rodent infestation increased gradually from tillering stage and reached a peak during the harvesting stage of the crop. Before adoption of the villages, rodent infestation increased from PI stage of the crop. After interventions, the LBC per hectare was also increased from tillering stage to harvesting stage. In the adopted village LBC was 3.40 in tillering stage and increased up to 4.60 in maximum tillering stage and then decreased again to 2.33 at harvesting stage due to intervention in terms of application of rodenticides (Zinc phosphide and Bromadiolone baiting. Similar trends were also observed in case of Trap Index and Cut tillers damage (Table 2).

KAP survey

The site for social engineering activity was selected in three villages viz.

(i) Adopted village: Napit; (ii) Partially adopted village: Balek and (iii) Control village: TakiLalung

Cropping system

Rice

Intervention

(1) Training. (2) Method demonstration of bait preparation and application and (3) Supply of inputs.

Questionnaire consisted of 55 questions under the head

(i) General information, (ii) Knowledge, (iii) Attitude, (iv) Practices.

Survey indicated that 68.70 % of the population was pure agriculturists while 31.30% had other livelihood also including services and small scale business. The cropping system was based on rice only. The details of the KAP analysis is given in the Table 3,4 and 5.

Plate: Activities during social enginneering on rodent control

Conducted training in Sikabamin village

Preparation of bait material

Translating lecture in local language

Group of farmers in trainings

Field visit on farmers field

Pineapple damage by rodents in Napit village

Table 2. Rodent activity in different villages of social engineering programmes during 2012 and 2014.

Stage of the crop	LBC ha^{-1}			Trap index			Rodent damage (% cut tillers)		
	Balek	**TakiLalung**	**Oyan**	**Balek**	**TakiLalung**	**Oyan**	**Balek**	**TakiLalung**	**Oyan**
Year 2012 (Before farmers campaign and before adoption of villages)									
Tillering stage	4.50	3.40	0.67	3.00	1.33	0.93	0.80	0.20	0.08
Max. tillering stage	8.90	5.60	1.33	4.00	3.33	1.25	1.90	2.46	0.92
PI stage	6.70	4.60	1.67	5.33	4.00	1.33	4.67	2.22	1.28
Ripening stage	4.40	5.20	1.87	8.00	12.67	4.87	5.56	5.80	2.16
Harvesting stage	5.10	4.80	2.00	12.33	10.00	6.33	4.30	6.60	2.90
Year 2014 (social engineering activity year)									
Tillering stage	3.40	3.87	0.50	2.13	1.33	0.87	1.20	2.17	0.00
Max. tillering stage	4.60	2.67	0.87	3.67	4.67	1.50	2.62	4.08	0.59
PI stage	2.50	4.25	1.33	2.00	3.50	1.67	2.47	3.93	1.51
Ripening stage	3.75	5.00	1.87	1.87	5.13	4.25	3.23	3.66	2.04
Harvesting stage	2.33	5.33	2.33	5.50	4.87	5.50	2.24	2.36	2.67

Table 3. KAP analysis report about *Knowledge*

Particulars	**Balek**	**TakiLalung**	**Oyan**
Knowledge			
1. Damage intensity (% per cent respondents)			
a) Low	17.65	20.83	52.63
b) Medium	82.35	79.17	47.37
c) High	0	0	0
2. Area of damage (% respondents)			
a) Store	17.65	12.50	21.05
b) Residence	11.76	8.33	31.58
c) Field	70.59	79.17	47.37
d) other	0	0	0
3. Rodent species prevalent in village			
1 species	0	0	0
2 species	0	0	0
3 species	58.82	66.67	26.32
4 species	35.29	25.00	68.42
5 species	5.88	8.33	5.26
4. Training attended: Not any farmer attended any training before interventions in all three villages.			
5. Rodent management			
a) Adopted	94.12	79.17	68.42
b) Not adopted	5.88	20.83	31.58
6. Management strategy adopted			
a) Mechanical	94.12	83.33	89.47
b) Cultural	5.88	16.67	10.53
c) Biological	0	0	0
d) Chemical	0	0	0

Table 4. KAP analysis report about *Attitude*

Particulars	**Per cent respondents**		
	Balek	**Taki Lalung**	**Oyan**
Attitude			
1. Best management strategy			
Mechanical	88.24	83.33	73.68
Cultural	5.88	8.33	10.53
Biological	0	0	0
Chemical	5.88	8.33	15.79
2. Success obtained			
Yes	29.41	16.67	31.58
No	70.59	83.33	52.63
3. Control create more problem			
Yes	5.88	12.50	15.79
No	94.12	87.50	84.21

Table 5. KAP analysis report about *Practices*

Particulars	Per cent respondents		
	Balek	TakiLalung	Oyan
Practices			
1. Weed management			
Yes	94.12	70.83	57.89
No	5.88	29.17	42.11
2. Repairing infested bunds			
Yes	94.12	91.67	89.47
No	5.88	8.33	10.53
3. Management in stores			
d) Use of Metallic bins	5.88	12.50	15.79
e) Cleanliness	17.65	16.67	21.05
f) Rodent proofing	76.47	70.83	63.16
4. Washing trap			
Yes	0	0	0
No	100	100	100
5. Kill the predators of rats:			
c) Kill	11.76	16.67	5.26
d) Not kill	88.24	83.33	94.74
6. Rodenticide use			
d) Not used	70.59	91.67	100
e) Zinc phosphide	17.65	0	0
f) Bromadiolone	17.65	8.33	0
7. Placement of rodenticide			
d) In burrow	17.65	0	0
e) Out side	11.76	8.33	0
f) Not used	82.35	91.67	100

LOCATION SPECIFIC PROGRAMMES

a. Collection, cataloguing and evaluation of indigenous rodent traps: In Arunachal Pradesh various techniques of rodent control are used by different tribes. These techniques includes in physical methods using locally available material for the control of rodent in fields. Now a days the farmers incorporated the iron or steel wire in its traditional equipments. In indigenous traps, the pre assessment and arrangement of rodent passage about 15 days prior to installation is required. Once a rodent is trapped in a passage with *uju* and *gorha* traps, the same passage is avoided by the other rodent when trapped rodent is left for a long time. Despite this, these rodent traps are much effective and popular in Arunachal Pradesh. The rodent meat is considered as a precious dish among all the tribal of Arunachal Pradesh for which the use of rodenticide is not preferred. The types of local traps used by the farmers are (i) *Etku* which is placed on passage of rodent in border of the field, along irrigation channels and bunds (ii) *Odde*to be installed in rodent shelter area near the field (iii) *Uju* trap is to be installed on a bridge made up of bamboo stick over irrigation channel and water streams from where the rodents are entered in the field and *Gorha* which is installed in passage with in the field and in front of burrows.

b. Studies on bamboo flowering *and* rodent out break: Bamboo flowering in *Dendrocalamus hamiltoni* was occurred in Geku circle of Upper Siang district and Korang village of East Siang district. The flowering starts from November, 2011 and continued upto May, 2012. Trap index and reproductive status of the rodents was recorded in flowering affected areas. The trap index (no. of animals/100traps/night) was 12.80 in flowering affected area where as 4.67 trap index was recorded in area which was away from flowering.

c. Monitoring of spread of *Bandicota Bengalensis* in Arunachal Pradesh: In East Siang district, the *B. bengalensis* was observed from jhum rice, WRC, maize, cabbage fields, tomato and cucurbits. During 2013-14, the highest relative abundance was found in maize crop (11.11%) followed by jhum rice (8.33%) and tomato (8.33%). The population of *B. bengalensis* was not found in beans and potato fields of East Siang district. *B. bengalensis* was more prevalent in West Siang districts, it is found in almost all the cropping systems except cucurbits. The highest species abundance was recorded in potato (12.5%) followed by brinjal (11.11%), tomato (6.67%), beans (6.67%), jhum rice (6.25%), maize (5.56%), WRC (5.41%) and cabbage (4.55%).

During 2014-15 surveys in East Siang district further confirmed incidence of *B. bengalensis* in jhum rice, WRC, maize, cabbage fields, tomato and cucurbits. The highest relative abundance was found in maize crop (38.46%) followed by tomato (25.00%) and potato (23.08%) in this year. In West Siang district, the population of *B. bengalensis* was found in almost all the cropping systems except beans and brinjal. The highest species abundance was recorded in cucurbits (40.00%) followed by maize (25.00%), potato (22.22%), tomato (20.00%), WRC (15.38%), cabbage (11.11%), and jhum rice (6.67%).

d. Collection of rodent species and development of rodent museum.

During the survey and population estimation of rodent in the region, different rodent species were collected in the laboratory. The collected specimens have been identification and preserved in the laboratory. Identified species listed below:

a) *Bandicota bengalensis* (Gray)
b) *Mus cookiinagarum* (Thomas)
c) *Rattus rattus* (Linnaeus)
d) *Rattus sikkimensis*
e) *Mus musculus*
f) Red billed Squirrel, *Callosciurus erythraeus*
g) Hoarybellied Himalayan Squirrel, *Callosciuruspyg erythrus*
h) Orange bellied Himayayan Squirrel, *Dremomys lokriah*
i) Particolored Flying Squirrel, *Hylopetesa lboniger*
j) Giant Flying Squirrel, *Petaurista petaurista*
k) Malayan Giant Squirrel, *Ratufabicolour*

PUBLICATIONS

1. Book Published:

Singh KM, Kumawat MM, Phurailatpam A, Rao VV and Pandey AK. 2013. Birds of Arunachal Pradesh (A compilation). College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh.

Singh KM, RK Patidar, Debashish Sen and M. M. Kumawat. 2015. Integrated Pest Management for Sustainable Agriculture. New Delhi Publishers, New Delhi. pp. 1-232.

2. Research paper/ Article Publications:

Kumawat, M.M. and Singh K. M. 2013. Population dynamics and management of mango leaf cutting weevil, *Deporaus marginatus*. *Indian Journal of Entomology*, 75(1): 62-67.

Singh, K. M., M. P. Singh and Kumawat, M. M., 2013. Entomophagy by the tribal communities of North East India. *Indian Journal of Entomology*, 75(2): 132-136.

Kumawat M.M., KM Singh, Debashish Sen and RS Tripathi. 2013. Threatened Rodent Species of Arunachal Pradesh. *International Journal of Agriculture, Environment and Biotechnology*, 6(4): 657-668.

KumawatM.M., K.M. Singh, R.S. Tripathi, TogeRiba, Siddhartha Singh &Debashish Sen (2014): Rodent outbreak in relation to bamboo flowering in north-eastern region of India, *Biological Agriculture & Horticulture*, DOI: 10.1080/01448765.2014.925828.

KumawatM.M., B.P. Mishra, Naresh Kumar and TogeRiba. 2013. Aran: A festival of

rodent hunting in Arunachal Pradesh. *Rodent News Letter*, 37 (3-4): 15-16

KumawatM. M. K. M. Singh, R. Patidar and R.C. Shakywar. 2014. Validation of biocontrol based IPM technology for pest of tomato in Arunachal Pradesh. In: V.V. Ramamurthy and S. Subramanian, Editors. Extended abstract in: National Symposium "Entomology as a science and IPM as a Technology- the way Forward" held on November 14-15,

2014. College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, pp. 171-172.

K. M. Singh, R. C. Shakywar and M. M. Kumawat. 2014. Integrated disease management for late blight and bacterial wilt in potato at different locations of Arunachal Pradesh. *HortFlora Research Spectrum*, 3(4): 361-364.

3. Book Chapter

K. M. Singh, M. M. Kumawat, M.P. Singh and T. K. Singh. 2013. Some important pests of citrus and their management. In: D. Prasad and D. P. Ray (Eds.). Biotechnological Approaches in Crop Protection. Biotech books, New Delhi, India, pp. 374-391.

Ashok Kumar and M. M. Kumawat. 2012. Biointensive Pest management in fruit crops. In: Advances in Biopesticides for IPM in Agro-ecosystem. Directorate of Research, PMUAT, Udaipur, pp. 194-204.

Teaching activities: Courses taught during the year are given as under:

S.N.	**Name of course**	**Credit hours**
1.	Insect pests of fruits, plantation, medicinal and aromatic crops	3 (2+1)
3.	Insect pests of vegetables, spice and ornamental crops	3(2+1)
4.	Apiculture	1(0+1)
5.	Fundamentals of Entomology	3(2+1)
6.	Forest Entomology and Nematology	3(2+1)
7.	Insect Ecology and Integrated Pest management including beneficial insects.	3(2+1)
8.	Insect Morphology and Systematics	3(2+1)
9.	RHWE (Rural Horticultural Work Experience)-- B. Sc. Hort. 4th year	
10.	FWE (Forestry Work Experience)- B. Sc. Forestry 4th year	
11.	Forest Protection (PG course)	2(1+1)

Central Agricultural University, Paisghat

Actual expenditure for the FY 2012-13 to 2014-15

(ICAR Share only)

(Rs. in lakhs)

Head/ Year	2012-13	2013-14	2014-15	Total
Pay & Allowances	0.00	0.00	0.00	**0.00**
T.A.	0.01	0.00	0.33	**0.34**
Rec. Contingencies	1.14	0.98	1.80	**3.92**
NRC	0.00	0.00	0.00	**0.00**
Total	**1.15**	**0.98**	**2.13**	**4.26**

KERALA AGRICULTURAL UNIVERSITY, THRISSUR - 680 656, KERALA

PART I: GENERAL INFORMATION

Project Title: All India Network Project on Vertebrate Pest Management – Rodent Control
Name of the Centre: College of Horticulture, Kerala Agricultural University, Thrissur - 680 656, KERALA

2. Report period: 2014 - 2015

3. Scientis – in – Charge (PI): Dr. Mani Chellappan

PART II: WORK ALLOTTED

1. Surveillance of pest rodents in predominant cropping systems; monitoring of rodent abundance and damage in selected agro-climatic zones of the region
2. Evaluation of new and safer rodenticides
3. Social engineering activity in rodent management

PART III: WORK DONE

1. SURVEILLANCE OF PEST RODENTS IN PREDOMINANT CROPPING SYSTEMS; MONITORING OF RODENT ABUNDANCE AND DAMAGE IN SELECTED AGRO-CLIMATIC ZONES OF THE REGION

Purposive and roving surveys were conducted to identify the rodent pest, population abundance and damage in coconut, cocoa, rice and cassava fields.

1.1. <u>Rodent pests and their damage in coconut</u>

Coconut palm is one of the most important traditional crops of Kerala. The commonly cultivated and indigenous varieties are, West Coast Tall (WCT), East Coast Tall (ECT), Lakshadweep ordinary, Lakshadweep micro, Chowghat Green Dwarf (CGD), Chowghat Orange Dwarf (COD) and hubrids viz., WCTxCGD and WCTxCOD. Rodents are a serious problem in coconut (Fig 1-2).Preliminary observations revealed that the differences in varieties do not make any changes in preference pattern for rodents irrespective of variations in quality and other properties of the kernel or volume of water inside the coconut.

Fig.1.Coconut damage by rodents

Two types of damage were recorded in coconut *viz*., damage to the nursery nuts and the other is on the crown of the palm. In the former case, the nuts were uprooted and the cabbage was completely eaten away by the rodents. In the latter case, the nuts right from the age of two to three weeks to the matured ones was damaged. Typically the damage on the nuts consisted of a single ragged-edged bore hole through the pericarp at the proximal end and in rare cases, at the distal end of the nut. The damaged nut eventually dropped in a span of three to seven days. Damage was severe in coconut gardens where the leaves of palms touched each other. Damage to nuts was not even and confined to five to twelve per cent of palms in the garden. Indian mole rat, *Bandicota indica*, *Indian* tree rat, *Rattus rattus wroughtoni* and coconut rat *R. r. rufescens* caused the damage to the nuts in the nursery and on the crown.

Fig.2. Coconut of various stages damaged by rodents

1.2. Rodent pest of cacao

Both rats and squirrels attack cocoa pods. Fully ripened pods were damaged more than the unripened ones. Rodents damage the epicarp of the pods by making hole and fish out the seeds along with the mucilaginous pulp; eat the sweet pulp and discard the seeds (Fig.3-4). Damage was more in the mixed farms where cacao plants intermixed with areca nut, pepper and rubber. Preliminary observations revealed that the damage was primarily due to three stripped squirrel, *Funambulus palmarum* during day time and rat, *Rattus rattus* in the night. Squirrel damage was more in hybrid cacao plants (up to 54%). Varieties *viz.*, Trinitario and criolla, the damage was negligible. Compared to squirrel, rat damage was low (30% on hybrids).

Fig.3.Damage by squirrels

Fig.4. Damage by Rats

1.3. Rodent pest of rice

Rat damage to rice started in the nursery itself. The sprouted seeds were eaten away by the field mouse, *Mus* booduga, House rat, *Rattus rattus*, lesser bandicoot rat, *Bandicota bengalensis* and larger bandicoot rat, *Bandicota indica* in the upland rice fields in Palakkad district. Tiller cutting was observed in isolated fields.

1.4. Rodent pest of cassava

Cassava or tapioca is one of the widely grown staple food of Kerala. Rodent infestation is one of the major problem in cassava cultivation (Fig.5). Rats viz., lesser bandicoot rat, *Bandicota bengalensis* and larger bandicoot rat, *Bandicota indica* extensively damage the cassava tubers. Regular field surveys were conducted to observe the rodent activity and observations *viz*., signs of rodent damage to cassava plants, number of

Fig.5.Rodent damage in Cassava

tubers lost per plant, etc. Maximum damage was recorded in cassava field where the crop was cultivated as intercrop in coconut plantations. The mean damage recorded was 28.0 per cent whereas the crop grown as mono-crop, the damage was 12.0 per cent.

2. EVALUATION OF NEW AND SAFER RODENTICIDES

2.1. Preliminary trial on rodent management in coconut

Trials in standalone coconut palms, plastic sheet stem banding of 60 cm width, at a height of 2-3m prevented the upward movement of rats from ground to crown (Fig.6).Along with the stem banding, crown cleaning and bromadiolane (Fig.7) cake(0.005%) placement on the stem as well as on crown had resulted in significant reduction in nut damage over a period of six weeks (Table 1).

Table 1. Effect of rodent management measures on mean nut damage in coconut (Pooled data)

Mean number of fallen nuts / palm/week before and after the treatment application						
Particulars	**Location**				**Mean nut fall count**	**% Reduction**
	Mathilakom	**SNPuram**	**Perinjanam**	**Kaipamangalom**		
Pre count (before rodent management treatment)	**5.0**	**5.9**	**4.7**	**4.7**	**4.85**	**0.0**
Observations after imposing rodent management treatment						
I week	2.1	0.5	0.8	0.9	1.09	77.6
II week	0.5	0.2	0.4	0.2	0.33	93.3
III week	0.3	0.2	0.4	0.1	0.25	94.8
IV week	0.3	0.1	0.1	0.1	0.15	96.9
V week	0.5	0.0	0.1	0.0	0.15	96.9
VI week	0.4	0.1	0.1	0.1	0.18	96.4
Weekly Mean damage	**0.68**	**0.18**	**0.32**	**0.23**	**0.36**	
Mean per cent damage reduction	**86.40**	**96.90**	**93.20**	**95.10**	**92.60**	**92.6**

Fig.6. Coconut trunk banding

Fig 7. Bromadiolone cake placement on coconut trunk

2.2. Preliminary trial on rodent management in Cacao

Harvesting ripened pods daily and removing the remnants of damaged pods regularly discouraged the rodents to damage cacao pods. Cutting of branches which touch other plants also reduced the damage by rodents. Spraying fish oil rosin soap (FORS 1.5%) and neem seed extract (0.5%) also deterred the rodents. Further studies are in progress.

3. SOCIAL ENGINEERING ACTIVITY IN RODENT MANAGEMENT

In coconut plantations of Mathilakom Block areas near Kodungalloor in Thrissur District, Kerala had a problem of unusual nut falling. It was alleged to be due to bat feeding as reported by the farmers.After ascertaining the causal agent, a frontline action research and demonstration was organized by the KAU personnel employing a user friendly technique of specially designed self-sticking polythene bands tied around the trunks at the ground level which yielded good results in reducing the nut damage.

Four frontline demonstrations were organized in four panchayats, viz., Mathilakom, Kodungalloor, Perinjanam and Kaipamangalom areas in Mathilakom Block jurisdiction. A block level meeting was organized for the aggrieved farmers from all the Krishi Bhavan areas in the Block Panchayat and reviewed the situation about the causal agent and their role in the present crisis. Four numbers of homestead plots were selected by the farmers themselves based on the severity of the nut damage. The co-operating farmers for the frontline research demonstrations were nominated to represent the four panchayat areas in the block jurisdiction. Ten numbers of severely affected palms with serious nut fall along with nut boring damage were selected from each homestead farms and were subjected to integrated management techniques.

1. Manual disinfestations by cleaning and sanitizing the coconut crowns
2. Plastic sheet wrapping of 45 cm width at a height of 1.5 m above the ground level to prevent the climbing access of rodents from below with specially designed sticky polythene sheet rolls
3. Application of bromadiolone (0.005%) bait cakes in the crown as well as tied up on the trunks

The experiment was executed and observations on further nut fall were made at weekly intervals consecutively for two months. Observations were taken on the cumulative number of freshly fallen coconuts with boring marks of uniform nature irrespective of the nut size at weekly intervals since the treatment application. The pre-treatment counts were considered based on the mean total number of the freshly fallen nuts during the prior week before the application. The night observations on the activity in the crown region of coconut palms revealed that the currently experienced economic loss of coconut with widespread nut fall was primarily due to the rodent depredations followed by bats as a secondary causal agent. The rat, *Rattus rattus, rufescence* was identified as primary pest followed by the flying foxes.

Analysis of the data from the respective sites in all the four panchayats as well from the pooled mean data revealed that the nut fall was significantly reduced by tree banding and the bait cake application. There was an average damage of 4.85 nuts per palm per week before the treatment application with the highest level of 5.9 at SN Puram and 4.7 each at Perinjanam and Kaipamangalam. Within one week after the treatment itself the mean number of damaged nuts dropped down to 1.085 nuts /palm. From II week on wards, the percentage reduction of damage increased above 93 per cent reaching to about 96 per cent reduction after the VI week.

This data evidentially highlighted the importance of the mechanical exclusion principles to prevent the access of the climbing rodents onto the palms to reach the crown for tender nut damage by boring into the tender nuts and the consequent fall of the same. The potential of the bromadiolone bait cakes applied in the crown as well as fastened around the tree trunk below might have also played their role in reducing the population of the rodents and consequent low nut damages.

KERALA AGRICULTURAL UNIVERSITY THRISSUR

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Total	0.00	**0.00**	**0.99**	**0.99**