Technical Bulletin No.3

FIFTEEN YEARS OF COORDINATED RESEARCH ON RODENT CONTROL

B.D.RANA
A.P. JAIN
R.S. TRIPATHI

PROJECT COORDINATOR'S CELL
ALL INDIA COORDINATED
RESEARCH PROJECT
ON RODENT CONTROL

CENTRAL ARID ZONE RESEARCH INSTITUTE
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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
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PREFACE

Indian Council of Agricultural Research, New Delhi, sanctioned an All India Co-ordinated Research Project on Rodent Control during October 1977 with four centres, viz., Central Arid Zone Research Institute, Jodhpur; Punjab Agricultural University, Ludhiana; University of Agricultural Sciences, Bangalore and Central Plantation Crops Research Institute, Kasaragod. CAZRI, Jodhpur was enshrined as the coordinating unit. Considering the diversity in rodent pest species and the cropping patterns in the country, four more centres were subsequently added to the AICRP during Sixth Five Year Plan. They are, ICAR Research Complex for North Eastern Hill Region, Shillong during 1982, Indian Institute of Sugarcane Research, Lucknow and Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 1983 and Andhra Pradesh Agricultural University, Hyderabad at Maruteru (west Godavari) during 1986. During the Seventh Five Year Plan two more centres, one at Gujarat Agricultural University, Junagadh and other at Dr. Y.S. Parmar University of Horticulture and Forestry, Solan were initiated under the AICRP. Two more centres viz , CCS Haryana Agricultural University, Hisar and JNKVV, Indore have been sanctioned during Eighth Five Year Plan.

The objectives of the Project are : To conduct basic and strategic research on rodent population, behaviour, biology, ecology and crop loss assessment under different agro-ecosystems. To coordinate Multilocation programmes on testing the efficacy of new technology for rodent control and to evolve suitable integration for developing viable rodent pest management models. To disseminate information and impart practical training for undertaking rodent control operations at community level.

The cooperating centres have, over the years, registered steady and constant progress on various frontiers of rodent research, especially on faunistic rodent complexities, crop losses, some basic physiological and behavioural aspects, rodenticidal toxicities and social engineering activities. Persistent efforts have been made to control the rodent menace by formulating suitable location specific package of practices.

One of the unique features of the Project has been "Social Engineering Activity on Rodent Control", wherein the farmers' fields serve as a real research laboratory. The timely demonstration and extension activities in adopted villages have made direct linkage with the ultimate clients, i.e. the farmers. Regular on-campus and off-campus training programmes of the farmers, linkage with Krishi Vigyan Kendras, State Agricultural Universities, State Departments of Agriculture, Forests, Horticulture, etc. and NGOs have been major focus of percolating research achievements.

Periodical publication of a quarterly "Rodent Newsletter" by the coordinating unit has provided a very convenient medium for rodent reseachers to disseminate new

observations and research results for peer enlightenment. The Newsletter has a wide circulation in the country and abroad. Effective interactions among rodent researchers of the country has also been achieved through the biennial workshops organised under the auspices of the coordinating unit at different centres. So far, seven such workshops and one National symposium have been organised. The coordinating cell has brought out several bulletins, monographs and reports on various aspects of rodent management. Besides these, the cooperating centres at Ludhiana, Jodhpur, Bangalore Jabalpur, Junagarh and Kasaragod have published bulletins/pamphlets in Hindi/ regional languages too for popularisation of the rodent management technologies.

The present bulletin is an attempt to collate the achievements of all the ten cooperating centres doing research for the last fifteen years. We hope that this compilation would be of great help to the rodent researchers.

We express our deep sense of gratitude to the ICAR for providing financial support and encouragement for this endeavour. We are also thankful to our colleagues at the cooperating centres for supplying the necessary informations and photographs for compilation of the bulletin.

We are deeply indebted to Dr. J. Venkateswarlu, Director, Central Arid Zone Research Institute, Jodhpur, for providing necessary facilities, guidance and encouragement in preparation of this bulletin. Secretarial assistance provided by Shri Harish Darwani, Mrs. Bhavani Bhaskaran and Shri Om Prakash Jayal is duly acknowledged for typing the manuscript in record time.

B.D. Rana
A.P. Jain
R.S. Tripathi

Jodhpur
21 March 1994

FOREWORD

Rodent menace has been realised almost by everybody. Their pestilence, health hazardness and broadening their activities towards underground fibre-optic cables and on earth surface and above in the aircrafts are real threat to mankind. The Government of India and the Indian Council of Agricultural Research have paid due attention towards growing rodent problem and opened a frontier of AICRP on Rodent Control in 1977 to combat this problem.

The AICRP on Rodent Control started at 4 centres has now covered almost all agro-climatological zones of country through its 12 centres. I am quite satisfied with the progress made by these research centres under the aegis of CAZRI as Coordinating Unit. I further feel that it is not only timely action but a need felt activity of CAZRI Unit to collate, compile and publish 15 years of Coordinated Rodent Research in India. I congratulate Dr. B.D. Rana, Project Coordinator and his team for bringing out such an excellent publication. This publication will be filling in gap between research and extension workers and policy planners. I hope and wish that this informative publication will be instrumental in combating rodent menace.

Jodhpur
21 March 1994

(J. VENKATESWARLU)
Director
Central Arid Zone Research Institute,
Jodhpur.

CENTRES OF ALL INDIA CO-ORDINATED RESEARCH PROJECT ON RODENT CONTROL

(Centres at Hisar and Indore are to be opened in 1995-96)

Introduction

1. Historical Background

Rodents being a serious competitior of mankind cause immense looses at every stage of crop production i. e. from sowing to harvest in the fields and in threshing yards and storage as well. They also transmit several deadly diseases to human being and its pets. Looking into the seriousness of the problem of rodents in agriculture, the Indian Council of Agricultural Research initiated an All India Coordinated Research Project on Rodent Control during October 1977. Initially, it was started at 4 centres in the country with Central Arid Zone Research Institute Jodhpur, as the Coordinating Unit. Besides CAZRI, Jodhpur, the other centres were (i) Punjab Agricultural University, Ludhiana (ii) University of Agricultural Sciences, Bangalore and (iii) Central Plantation Crops Research Institute, Kasaragod. Considering the diversity in rodent species and cropping pattern in the country 6 more centres were added later on. These are : Indian Institute of Sugarcane Research, Lucknow, Jawaharlal Nehru Krishi Vishva Vidyalaya, Jabalpur ICAR Research Complex for NEH Region, Shillong, A.P. Agricultural University, Hyderabad (During VI Five Year Plan) and Gujarat Agricultural University, Junagadh and Dr. Y.S. Parmer University of Horticulture & Foresty, Solan (during VII Five Year Plan). For conducting area specific research on soybean and vegetable crops, two more centres at Indore and Hisar have been sanctioned during VIII Five Year Plan period.

2. Mandate and Objectives

Following are the important mandates and objectives of the AICRP on Rodent Control :

(i) To study the species composition, population dynamics and feeding cycle of rodent pests in relation to various agricultural crops.

(ii) To study the bait preferences among different rodent species to establish effective baits and additives for preparation of effective and palatable baiting.

(iii) To evaluate the lethal toxicity, efficacy and palatability of newer rodenticides in laboratory and field condition in different agroclimatic zones of the country.

(iv) To study the phenomenon of bait shyness among economically important rodents with a view to investigate ways and means to remove its derogatory influence on control operation and to enhance the efficiency of rodent control programmes.

(v) To study and establish the basic behavioural patterns of different rodent species with a view to evolve effective techniques of rodent pest management.

(vi) To find out if either sex of various rodent species secrete/excrete any sex attractants.

(vii) To evaluate the losses caused by rodents in major cereal crops, pulses, oilseeds, planation and horticultural crops.

(viii) To educate and train the farmers and farm advisory workers on rodent management techniques.

(ix) Social engineering activity on rodent control, an extension oriented large scale field trial on latest package of rodent management technologies at farmers' fields and in rural residential premises.

(x) To assist state departments of agricultural and forests in organising large scale rodent control programmes.

3. Organization and structure

3.1. The set up :

The project is headed by the Project Coordinator stationed the Central Arid Zone Research Institute Jodhpur. It has ten cooperating centres spread in different agroclimatic zones of the country. Of them four centres are located in ICAR Institutes and the other six are in State Agricultural Universities. The name of centres, their year of commencement and period of operation is presented in Table 1 and Fig. 1.

Table 1. Organisational set up of AICRP on Rodent Control.

S. No.	Centre	Located at	ICAR/ SAU	Year of start	Period of operation (years)
1.	Jodhpur (Raj.)	Central Arid Zone Research Instt., Jodhpur.	ICAR	1977	15
2.	Kasaragod (Kerala)	Div. of Entomology Central Plantation Crops Research Institute, Kasaragod.	ICAR	1982	10
3.	Ludhiana (Punjab)	Dept. of Zoology, Punjab Agril. University, Ludhiana.	SAU	1977	15
4.	Bangalore (Karnataka)	Dept. of Vertebrate Biology, University of Agril. Sciences, Bangalore.	SAU	1977	15

5. Shillong (Meghalaya)	Div. of Entomology ICAR Research complex for NEH Region, Shillong.	ICAR	1982	10
6. Lucknow (U.P.)	Rodent Res. Centre Indian Instituture of Sugarcane Research Sardarnager, Gorakhpur.	ICAR	1983	9
7. Jabalpur (M.P.)	Dept. of Entomology J.N. Krishi Vishva-Vidyalaya, Jabalpur.	SAU	1983	9
8. Hyderabad (A.P.)	Agril. Research Station (A.P.A.U.) Maruteru (West Godawari)	SAU	1986	6
9. Solan (H.P.)	Dept. of Entomology Dr. Y.S.P. Univ. of Horticulture & Forestry. Solan.	SAU	1987	5
10. Junagadh (Gujarat)	Dept. of Entomology College of agriculture (GAU), Junagadh.	SAU	1987	5
11. Hisar (Haryana)	Dept. of Zoology C.C.S. Haryana Agril Univ. Hisar.	SAU	To be opened during 1995-96	
12. Indore (M.P.)	Agril. Res. Station J.N.K.V.V., Indore.	SAU	To be opened during 1995-96	

3.2. Infrastructure :

The Project Coordinating unit was functioning along with the Jodhpur- Coop rating Centre till 1989 with following staff :

1.	Project Coordinator	— One
2.	Scientist S-2	— One
3.	Scientist S-1	— Two
4.	Technicai Assistant	— Three
5.	Laboratory Attendant	— Three
6.	Peon	— One
7.	Jr. Stenographer	— One
8.	Jr. Clerk	— One

During 1989 Central Arid Zone Research Institute, Jodhpur was reorganised and the Cooperating centre was seperated from the Project Coordinator's Cell and functions with the Division of Animal Sciences and Rodent Control of the Institute.

The detailed staffing pattern at various centres is given in Annexure 1.

3.3. Area of Research :

Besides multilocation research studies each centre has been entrusted with specific areas of research in respect of crops or commodities on which greater emphasis is to be laid for evolving ecologically sound, economically viable and sociologically acceptable rodent management technolgies (Table 2).

Table 2. Specific areas of research at various centres.

Name of the Centres	Crops/commodities dealt with
Central Arid Zone Research Institute, Jodhpur	Arid Zone food crops, horticultural crops, grasses and tree plantations.
Punjab Agricultural University, Ludhiana	Irrigated cropping systems.
University of Agricultural Sciences, Bangalore	Dryland crops, Cardamon etc.
Central Plantation crops Research Institute, Kasaragod	Plantation crops.
ICAR Research Complex for NEH Region, Shillong	NEH crops (Paddy, maize pineapple).
J.N. Krishi Vishawa Vidyalaya Jabalpur.	Pulse crope
A.P. Agricultural University, Maruteru (West Godavari)	Wetland paddy.
Indian Institute of Sugarcane Research, Lucknow (Sardarnagar, Gorakhpur).	Sugarcane-Wheat-mustard.
Gujarat Agricultural University, Junagadh.	Groundnut
Dr. Y.S. Parmar University of Horticulture and Forestry, Solan.	Horticultural crops.
*CCS Haryana Agril. University, Hisar.	Vegetable crops.
*JNKVV, ARS, Indore	Soybean

* To be opened in 1995-96

3.4. Workshops :

Organisation of the Workshops is one of the major objectives of the Project to assess the achievements, workout the reeommendations of rodent management and

to finalise the future research programmes after thorough discussion among various rodent scientists drawn from the coordinated project and self funded centres. So far seven such workshops have been organised at different centres, as per the detail given in table 3.

Table 3. Details of the All India Workshops on Rodent control.

S.No.	Year	Perion	Venue
1.	1978	8-10 July	CAZRI. Jodhpur
2.	1980	18-21 Aug.	UAS, Banglore
3.	1983	14-16 March	CAZRI, Jodhpur
4.	1985	28-30 Nov.	IISR, Lucknow
5.	1988	24-26 Feb.	ICAR Res. Complex for NEH Region, Shillong
6.	1990	12-14 April	Dr. Y.S.P. Univ. of Hort. & Forestry Solan
7.	1991	13-14 Nov.	CAZRI, Jodhpur.

Besides the workshops, a tow day National Symposium on Rodent Pest Management—A Scenario for the 21st Century was also organised at CAZRI, Jodhpur during November 15-16, 1991.

3.5. Documentation :

One of the major endeavoures of the AICRP has been documentation of various research results in form of reports, proceedings, mimeographs, monographs etc. RODENT NEWS LETTER, a quarterly publication of the Project has provided a convenient medium for rodent workers round the country and abroad to disseminate interesting, new observations and research results. Two special issues of Rodent News Letter, one devoted to techniques of rodent research and other devoted to National Symposium on Rodent Pest Management, have created a special interest among readers. Some of the reports and monographs released by the AICRP are detailed below :

1. Annual Progress Reports of the AICRP on Rodent Control.
2. Proceedings of the All India Workshops held at different centres since 1978.
3. Evaluation of second generation anticoagulant rodenticides in India I: Bromadiolone, Jodhpur pp-1-20 (1986).
4. Evaluation of second generation anticoagulant rodenticides in India II: Brodifacoum, Jodhpur. pp-127 (1988).
5. Social Engineering Activity on Rodent Control-A case study, Jodhpur pp 1-20 (1988).

6. Glue traps-An evaluation Report, Jodhpur. pp-1-17 (1988).
7. Ecology of the Indian desert gerbil, *Meriones hurrianae*, CAZRI monograph. pp 1-88 (1981).
8. Chooha Prabandh-Ek Awashyakta, Kyon aur Kaise? CAZRI Monograph No. 35. pp-1-20 (1988).
9. Major rodent pests of agriculture in India-An illustrated guide. CAZRI, Jodhpur. pp 1-14 (1988).
10. Rodent pest Management-A Training manual CAZRI, Jodhpur pp 1-67. (1988).
11. Rodent pest Management-The State of Art. CAZRI, Jodhpur. pp 1-38. (1993).

Different AICRP cooperating centres have also published pamphlets, leaflets etc. in regional language for popularisation of rodent management technologies and the Project Scientists have delivered talks on rodent management at various All India Radio Stations.

4. Training and education:

Since rodent management technologies are easy to operate and are quick result orientsd and cost effective, these can be translated into practice in the farmers fields. But, for proper transfer of technology, all the strata dealing with extension and education need to be invariably trained. The AICRP on Rodent control has taken all the starta into consideration for training. Following types of trainings are organised by the AICRP at different centres.

4.1. Apex Level Training :

This training is imparted to the officials of Departments of agriculture, food, health, railways, forests, aviation etc. It is organised under the aegis of National Programme on Rodent Management formulated by Govt. of India duing 1975. The Coordinating centre of the Project at CAZRI, Jodhpur is organising this training course since its inception. In addition to this, the APAU, Maruteru Centre also organises this training Programme at Hyderabad/Maruteru in collaboration with Central Plant Protection Training Institute; Hyderabad. Recently, the Shillong Centre of the project has also been entrusted to organise such a course for the officials of North-Eastern Hill states. Besides the technical know how on management of rodent pests the contents of the courses also emphasizes the transfer of technology, type of training required for lower strata, man management, moulding the attitude and behaviour of the people towards rodent pest management and on effective communication.

4.2. Field Level Training :

All the AICRP centres organise such trainings as off campus/on campus for educating the farmers of adopted villages under various technology transfer

programmes like ORP, KVK and lab to land programmes etc. Rodent control campaigns are also organised by the AICRP centres at village level during summers.

4.3. Media utilization :

The Project Scientists utilize various media like, All India Radio, Doordarshan and Print media for imparting mass education about the problem of rodents and their management. Besides this the Jodhpur centre collaborated with Audio Visual Research Centre, Ahmedabad for preparation of two video films for U.G.C. net work. The Ludhiana and Bangalore centres have also developed video films on rodent pest management for mass education.

5. Linkage :

During the last 15 years the AICRP has developed a close net work of liason with various State and Central Departments, Universities, Autonomous organisations through Apex Leval trainings, workshops, symposia, Project publications and Rodent News letter. Intimate interactions with ICAR institutes, Agricultural Universities, Directorate of Plant Protection Quarantine and storage, Central Food and Technological Research Institute, Mysore, indian Grain storage Institute, Hapur Zoological survey of India and State Departments of Agriculture, forest and Health has helped immensely in developing strategies for viable rodent management technologies in various agroecological zones of India. We have also interacted with indian Council of Medical Research, Indian council of Forestry Research and Education, Defence Research and Development organisation, Department of Civil Aviation etc. During the last five years, the AICRP developed close linkage with Deptt. of Railways and Dept of Telecommunications for developing rodent proof technology for fibre optic communication systems. The Project has also given advisory services to International Air Port Authority of India, Railway Board and Indian Air force. The Project workers have regularly provided rodent control advisory services to poultry farmers and hospitals. The Project Scientists continue periodical interactions with various International Institutions and societies engaged in Rodent research and documentation.

University of Agricultural Science, Banglore

1. Introduction

The Ford Foundation which was very much involved in aiding and strengthening of research in plant Protection at this University made it a point to support a special Project on Vertebrate Biology at the University of Agricultural Sciences, Bangalore. The Vertebrate Biology Department is engaged in research related to rodent management. Both field and basic research work are the chief responsibilities of this unit.

The grant provided by Ford Foundation terminated during December, 1977 Realizing the lacunae and great need for strengthening research efforts in the field, Indian Council of Agricultural Research, New Delhi, initiated a Cooporating Centre of All India Co-ordinated Research Project on Rodent Control during 1978 with the following mandate :

1. To study the species composition, population dynamics and breeding cycles of rodent pests in relation to various agricultural crops.
2. To study the bait preferences, lethal dosages of rodenticides and establishment of control techniques.
3. To study and establish the basic behavioural patterns and phenomenon of bait shyness in economically important rodents with a view in utilizing this information for enhancing the efficacy of rodent control procedure.
4. To educate and train the farmers to adopt rodent control procedure.
5. Social Engineering activity in rodent control-An extension oriented large scale field project.

2. Species composition of rodents

2.1 Dry land cropping system

The relative abundance of the rodent species varied from year to year and *Tatera indica* was the dominant species followed by two species of *Mus* and *R. meltada*. The peak population of these rodent species were seen during January, June, and September (in 1980) January, April, September (in 1981), and during September (in 1982). The rodents were completely absent during March and May 1980, August, 1981, April, May, July and December, (in 1982) of a calender year. The study showed that rainfed ragi fields were infested mainly by gerbils, followed by two species of *Mus* and *R. meltada*.

2.2. Wetland cropping system :

The predominant species of rodent include *M. booduga* followed by *F. palmarum*, *B. bengalensis*, *S. murinus* *M. platythrix*, and *T. indica*. The study indicated that *B. bengalensis* may not be the only predominant species in wet lands. The observed variation in corrected per cent trap success during the study period could be due to the removal of fodder and sugarcane in the fields providing additional harbourage for rodent population. The two peaks (*B. bengalensis*) population seen during April and October, agree with our earlier reports. The study also indicates that if the predominant species is removed by proper control measures, other rodent species dominating the fields are not ruled out.

2.3. Southern transitional zone :

Studies conducted at Regional Research Station Navite (Shimoga Distt) indicated presence of *R. meltada*, *B. bengalensis* and *T. indica* in winter season whereas in summer (1992) only *R. meltada* were trapped.

2.4. Coastal zone :

This zone was found to be predominantly inhabited by *Rattus rattus* wroughtoni followed by *R. I. rufesens*, *Funambulus tristriatus*, *T. indica*, *B. bengalensis* and *M. booduga*, *Rattus blandfordi* and *Vandaleuria oleracea* occurred in lesser proportions. Infestation and burrow system of *Hystrix indica* were also noticed.

3. Behavioural Studies

3.1. Bait Preferences :

Studies carried on bait preference in *Bandicota bengalensis*, *Bandicota indica*, *Mus booduga*, *Rattus meltada* *Mus platyhrix* and *Tatera indica*, indicate that broken rice with 10% groundnut oil as the best bait for *B. bengalensis*, whole rice with 10% groundnut/gingili oil for *Mus booduga*, broken ragi with 10% gingili oil for *Mus platythrix* and whole ragi with 1% groundnut oil for *Tatera indica*. Studies on bait preference of the other economically important species of rodent around Karnataka, is in progress. Further it is quite possible that results obtained from experimentation of field rodents under laboratory conditions may not apply to field conditions, hence studies on food preference of rodents in paddy, ragi and sugarcane fields were carried out. Paddy fields were infested by *B. bengalensis* and *R. rattus* While ragi and sugarcane had only *B. bengalensis*. In all the three habitats rice was the most preferred cereal and maize the least liked. Ragi field rats consumed highest amount of cereals per unit area followed by paddy and sugarcane fields.

3.2. Bait Shyness :

Development and persistance of bait shyness towards zinc phosphide and RH-787 were studied in *B. bengalensis*. *B. indica* *M. platythrix* and *T. indica*. The cereal

baits selected to carry the poisons for different species were based on earlier laboratory experiments on food preferences.

In *B. indica*, zinc phosphide ingestion was followed by bait avoidance upto 60 days. Only after 105th day the bait shyness completly disappear and vacor ingestion induced bait shyness upto 30th day, was observed.

In *B. bengalensis*, zinc phosphide and RH-787 revealed that the rat becomes avert only towards the former poison after consuming sublethal quantities of it. This aversion persisted for 30 days. During RH-787 treatment, the animals failed to exhibit bait shyness.

Further tests on bait shyness in *B. bengalensis* showed that once bait shyness develops towards sublethal doses of zinc phosphide and RH-787; it persists inspite of changing bait, poison or both. In adition, bait shy subjects become more neophobic towards new foods. Similar experiments on *T. indica* showed that bait shyness resulting from sublethal poisoning of 'RH-787 and zinc phosphide extended to both cereal and oil component of the bait. Not only the poison associated bait, but also poison, new bait new poison were rejected in comparison to an earlier experienced, less liked but harmless food.

In *Mus platythrix*, 0.05% zinc phosphide induced bait shyness after single ingestion which persisted upto 110 days. 0.5% 'Vacor' induced bait shyness after single consumption which lasted for 120 days.

Silmurin : Ingestion of 0.04% silmurin in ragi bait did not affect its preferential intake compared to the alternate, non-lethal wheat confirming that the poison does not induce any bait shyness.

3.3. Hoarding Behaviour :

Amongst cereal only maize was stored, while the preferential order of pulse was groundnut, cowpea, green gram in both the species. Female *B. bengalensis* hoarded more pulses than cereals. Gerbils did not exhibit any such sexual dimorphism. While larger grains and whole pellets were preferentially hoarded by lesser bandicoots, gerbils preferred to hoard larger pellets, size having no effects on hoarding. Presence of nesting material decreased hoarding tendency except in female gerbils where as food deprivation elicited higher hoarding in males of both the species *B. bengalensis* hoarded more grains and pellets than amount consume, whereas in *Tatera indica* only pellets were hoarded more than the quantity consumed.

3.4. Behaviour under Food and water Deprivations

Bandicoot rats were capable of losing weight upto 80% body weight and still live for three more days. The food deprived animals take 12 days to die, where as the

period ranges from 6-12 days in case of food and water deprived animals. Bandicoot showed the capacity to withstand thirst upto 80 days. Hunger brings about sharp decline in the general activity. However agonistic interaction in the three kinds of stressed conditions increased from the second day onwards. The extent of agonistic behaviour is more in food deprived group than other stress subjected groups. The frequency of occurrence of exploratory behaviour ceased on 10th day for food deprived, on 12th day for water deprived and on 14th for food water deprived rats.

3.5. New food Reaction :

B. bengalensis and *R. rattus* did not exhibit new food reaction but both *R. meltada* and *T. indica* exhibited the phenomenon. While *R. meltada* was neophobic towards all new food and was consistent in refusing such foods, *T. indica* was hesistant in refusing such foods only in the initial stages.

Mus platythrix : Change in diet from one food to other as in the case of rice to ragi to wheat, wheat to jowar, jowar to maize was always accompanied by a reduction in food intake suggesting that *M. platythrix* avoids new foods.

Mus booduga : The reaction of *M. booduga* to new foods was similar to *M. platyhrix* and consisted of reduction in intake whenever food was suddenly changed.

3.6. Food Preferences :

i) *B. bengalensis*: Postweaned litter of *B. bengalensis* condition fed on rice, ragi and laboratory feed during their infancy preferred these to novel foods when tested later. The preference developed for rice early in life did not wane. The duration of infant exposure did not affect retention and formation of preferences. Further studies on food experience during preweaning period indicated that food preferences are acquired only from 9th day after birth. Food exposed earlier to this date did not influence adult diet selection in *B. bengalensis*.

ii) *M. booduga* : Tests indicated that early exposed diet influenced adult food selection positively. Further tests suggested that there is a sensitive period (4-6 days after birth) during which long lasting preferences for foods are established in this wild mouse.

3.7. Intraspecific Interactions :

i) *Non-aggressive social behaviour in B. bengalensis* : This included frequency of occurrence of approach, nosing, nose-nose investigate ano-genital sniffiing, push-past, crawling under/over, buddling, grooming and sexual and was studied in male-male, male-famale and female-female and group interactions for their rhythmicity. The species exhibited 95% rhythmicity for social behaviour but rhythms were uni or bimodal and were influenced by the number and sex of interacting conspecifics. Peaks occurred at 0900 and males were socially more active than females.

(ii) *Rhythms of aggressive behaviour* : As in social behaviour, the number, intensity and duration of aggressive behaviour peaks depended on the number, sex and social status of the interacting conspecifics. Peaks of aggression occurred during dark period. Both sexes were belligerent in heterosexual conflicts. But during male-male interaction and one-male with two/three females, one male in the former and the male in the latter was dominant. In cases involving 2/3 males with a single female, *alpha* and *omega* types could be identified.

(iii) *Inter-specific interactions* ; Studies of intra-and inter species encounters between isosexual and heterosexual pairs of *B. bengalensis T. indica R. rattus* and *R. norvegicus* showed that all interaspecies, biosexual, paired, interactions were amicable except that of *B. bengalensis*. Except the intraspecies pairs of *R. rattus* vs *R, norvegicus* and *T. indica* vs *R. norvegicus* other pair combination were agonistic The order of aggressive behaviour was *B. bengalensis, T. indica R. rattus, R. norvegicus* and for amicable behaviour *R. rattus, R. norvegicus, B. bengalensis, T. indica.*

4. Ecological Studies :

To assess the incidence of damage in relation to crop condition and the fulfilment of dietary requirement during the non-cropping season, the feeding habits of *Bandicota bengalensis* (Gray), a potential pest in the crop fields, were studied. Food preference under the laboratory condition was undertaken to rank the preference between rice, ragi (Millet), groundnut, standard food, *Panicum repens* and other grasses. The Bandicoot rat causes damage by feeding and hoarding food during the flowering of the paddy crop apart from the damage done to grain nearing maturity in irrigated fields. However no incidence of damage was observed in the early stages of ragi and groundnut crops in both irrigated and non-irrigated fields. The quantity of grain hoarded in the burrows of the Bandicoot rat appears to depend on sex and the sexual state of the animal. According to the crop condition and the availability of food, feeding habits of the rat alter. When necessary the diet is supplemented with the naturally available rhizome of *P. repens*. This adaptation of the Bandicoot rat clearly demonstrates its potential as a pest of agricultural crops.

Population movements are not restricted by water channels in the field. Sub-adults usually migrate from field to field establish settlements in abandoned burrows. They dig individually their own pests or food chambers in the newly occupied burrows.

5. Evaluation of rodenticides :

Very little is known about the toxicology of various rodenticides to the major rodent pests of Karnataka, to find out the most effective poison and its minimum lethal dose for various rodent pests, experiments were under taken in our laboratory. The present report highlights the important results of our laboratory and field trials.

(i) *Zinc phosphide and RH-787* : LD_{50} of zinc phosphide for *B. bengalensis* was found to be 20 mg/kg body weight when offered with plain bait. Field trials with RH-787 and zinc phosphide indicated, 1% RH-787 giving 83% reduction of field rodents and 2% zinc phosphide showing 79.9% mortality of *B. bengalensis* in paddy fields and 73% in ragi fields. Zinc phosphide at 1%, 2% and 3% in bait resulted cent per cent mortality of *M. platythrix* and in case of *T. indica* cent percent mortality was recorded at 2% zinc phosphide.

(ii) *Aluminium phosphide trials* : Data on Aluminium phosphide fumigation trials on *B. bengalensis, Tatera indica* and *M. platythrix* showed cent percent mortality occurring early in humid chambers (0.5 g). The time to death was size dependent since the larger bandicoot rat, took the longest duration to die. Higher concentration of Aluminum phosphide gave better results in conditions of lower humidity, which was also true in laboratory trials. One pellet per burrow (0.6 g) was effective in wet lands and 2 pellets (1.2 g/burrow) in dry lands. Two days of treatment is necessary for effective control. The fumigant reduced 87% and 89% of active burrow in wet and dry land respectively. In addition, arsenic oxide and thalium sulphate, were, also screened against rodent pests.

(iii) Barium carbonate : The effective concentration of Barium carbonate was tested in *B. bengalensis, Mus. platythrix* and *Tatera* in the laboratory. The cent per cent mortality was achieved for *B. bengalensis* at 5% *Tatera indica* at 10% and *M. platythrix* at 7.5%. The field studies yielded 80% reduction in the *B. bengalensis* population in agricultural fields of Main Research Station, UAS, Hebbal, Bangalore.

(iv) Bromadiolone : Studies using different concentrations of Bromadiolone by oral intubation method showed that at 10 mg/kg dose, cent per cent mortality occurred in *Bandicota bengalensis* while in *B. indica* 100% kill was achieved with 5/mg /kg dose. Probit analysis showed LD_{50} = 5/mg/kg for *B. bengalensis* and LD_{50}= 2 mg/kg for *B. indica*. The trials on LFD_{50} are in progress. Preliminary results show that 0.005% poison in bait needs 1 day feeding for *B. indica* and 2 days for *B. bengalensis*.

Bromadiolone on *Rattus meltada :* Although 0.001 to 0.007% conc. of bromadiolone cause 100% mortality in *Rattus meltada* but the duration for death varies between concentrations. 0.005% to 0.006% conc. results in least duration for death (4.22 days), and prebaiting before Bromadiolone treatment does not improve bait consumption. Further among the rodenticides, evaluated in fields with Rodarfain, Zinc phosphide, and Aluminium phosphide, Bromadiolone (70% success) was better than rodafarin (166% success) in effectiveness.

(v) *Silmurin and Racumin* : The lethal feeding dose (LFD_{50}) of silmurin was found to be 49.2 mg/kg and 42.85 mg/kg body weight for male and female gerbils

respectivejy. However, cent per cent mortality was obtained at 0.1 per cent concentration for both the sexes.

The LD_{50} values of the racumin an anticoagulant was found to be 10.72 x 5 mg /kg and 7.24 x 5 mg/kg body weight for male and female gerbils, respectively. However cent percent mortality was observed at 0.04% and 0.03% concentration for male and female gerbils. All the concentrations evaluated against *R. meltada* and *T. indica* resulted in 100% mortality. The average daily intake with 0.075% conc. of Racumin in bait was highest and the duration of death of lowest. Duration of death was longer with lower doses of 0.05 and 0.06%, hence 0.075% was considered optimal for control of both these species. Interestingly, choice tests on *R. meltada* and *T. indica* indicated existence of poison shyness by reduction in quantity poison consumption. Further, monthly trials on poison bait did not record any improvement on its consumption except with *T. indica* during trial (August), thus indicating persistance of poison shyness in both the specie.

(*vi*) *Brodifacoum :* Preliminary laboratory trials were undertaken to evaluate the efficacy of liquid brodifacoum on *B. bengalensis* and *T. indiea.* The pilot observations indicated that after a single exposure of rodenticide (0.005%), cent percent mortality was recorded in both the species of rodents after 3rd day of poison treatment. Further with rise in the rodenticide concentration (0.007%) cent percent mortality was also achieved in *T. indica* within 8 days of the rodenticide treatment. The laboratory trials are in progress for conclusive data. Wax cake of 0.005% brodifacoum resulted in 100% mortality of *R. meltada, T. indica* and *B. bengalensis* in 24 and 48 hr exposure. Amongst the three, *T. indica* was more susceptible. *R. meltada* took more days to die, *B. bengalensis* seemed more susceptible to the cakes than *R. meltada.*

(*vii*) *Cholecalciferol* : Among various formulations tested in choice studies against *B. bengalensis* it was cereal pellet cake. The bandicoot registered 60% mortality in 6-15 days and *T. indica* registered only 40% mortality in 7-10 days. The a.i. intake of cake by *B. bengalensis* was 0.39 mg/kg/day whereas it in *T. indica* was 0.26 mg/kg/day. The corresponding figures for pellet bait was 0.31 and 0.56 mg/kg for *B. bengalensis* and *T. indica*, respectively.

6. Evaluation of Bromodiolone in dryland croping systems :

(*i*) *Field Trials* : The percent reduction in live burrow coconut (LBC) ranged from 77 to 93% in various agro-ecosystems. In ridge gourd, grape garden and mixed plantation there was no difference in the efficacy of bromodiolone in cake form and poison offered in loose bait. However when the two forms were tried in adjacent tomato and ragi fields, the cake bait gave a spectacular reduction of 93% in burrow count compared to 78% reduction when poison was mixed with loose bait.

Population reduction as measured by % trap success indicated a higher reduction consequent to bromadiolone baiting. The success was 100% in all fields with the exception of Tomato fields where it was only 80%.

(ii) Trials in Residential premises : Bromadiolone treatment resulted in 75% reduction in house rats as estimated by trap success in Shanbogonahalli colony and by 72% as measured by census baiting. The cake and loose baits did not differ much in there potency as seen by 73.78% and 70.06% reduction in bait consumption after treatment. In chokkanahalli the respective figures for the two types of poison formation were 80.83% and 81.95% reduction. The percent decrease as measured by tray success was 100% in this village as well as in Doddatumkur. However in the latter which consisted of a single house, one pumphouse and a small poulty unit, the post-treatment consumption was higher due to feeding by poultry birds at the fence.

Prior to poisoning *T. Indica, M. booduga, B. indica* and *R. meltada* inhabited the fields. The post control studies showed occurrence of *R. rattus M. platythrix* and *Suncus murinus*. In the house only *R. rattus* oocurred both prior to and after bromadiolone poisoning.

(ti) Rodent control in plantations : It has been observed that *R. rattus, R. meltada* and *M. booduga* are commonly found in the crown and *B. bengalensis* occurs in the nurseries.

Damage : The damage was least in younger trees and maximum in older palm. Hoever tender coconuts were damaged upto 89.5% while the mature nuts were destroyed to the extent of 52% when intercrops were grown and upto 49% in the absence of intercrops. Based on damaged fallen nuts, loss to coconuts is 45.32 nuts/tree/year resulting in 51.15%.

(iv) Integrated management : Trapping, employing snap and live traps at crown and ground level was ineffective. Five percent zinc phosphide, 0.25% bromadiolone and 0.005% rodafarin baiting at crown level resulted in 100% reduction in fall of damaged nuts. The cost of operation works out to be Rs. 112.95 for zinc phospide, Rs. 90.5 for rodafarin andRs. 87.5 for bromadiolone per 100 trees.

(v) Laboratory and field evaluation of shell rodenticide WL 108366 (Flocoumafen) In the choice feeding tests carried out in the laboratory using 1% Master mix of the shell Rodenticide 'FLOCOUMAFEN' 100% mortality was registered in all the three spec as of rodents namely *B. bengalensis T. indica* and *R. meltada*. Mortality of the rodents pests standard from 4th day onwards upto 12th day in case of rodents exposed for 24 hours of poison baitng and the same was further reduced to 9th day in case rodents exposed for 48 hours. Pulse baiting of the live burrows of *B. bengalensis* in paddy fields (pre harvests stage) resulted in 80% control on 8th day and

88% control on 11th day after poison treatment.

vi) *Comparative evaluation of rodenticides and trapping in poultry farms* : The major objectives were (1) Comparatative seasonal evaluation of different rodenticides viz., rodafarin (0.025%), zinc phosphide (2%), bromadiolone (0.005%), brodifacoum (0.005%), and trapping as a method of control in Poultry Units at Hebbal, Bangalore and nearby village namely Sriramapura (2) Evaluation of Rodent Control using zinc phosphide (2%) followed by aluminium phosphide fumigation in layer houses at Thimmansandra (3) Evaluation of bromadiolone and brodifacoum wax cakes in hatchery layer houses at Doddatumkur (4) Field Evaluation of ibuprofen and phenybutazone potentiated bromadiolone and brodifacoum at Hesaraghatta.

Trapping was least successful during rainy season (20%) but increased during winter and summer seasons (75%). zinc Phosphide was not effective recording only 36-47.6% reduction of rodents during different seasons. Rodafarin was also less effective reducing pest populations from 33.3% to 46.6% during the different seasons of the year. Bromadiolone reduced 56% pests during summer, 47 to 55% in rainy season but only 35-37% during winter. Brodifacoum eliminated 60-67% rodents during rainy season, 57-68% in winter and 60-74% in summer. The overall efficacy of the methods employed was Brodifacoum (65%) > trapping (51%) > Bromadiolone (48%) > Rodafarin (43%) > Zinc phosphide (41%). Analysis of data as to differences in the efficacy of rodenticides in various poultry units, between seasons, between rodenticides, season and poultry units were carried out by 2x5x3 factorial design. There was no significant difference between the two poultry units in the efficacy of different control methods. However interaction between poultry units as well as rodenticides, seasons and poultry units was highly significant.

Zinc Phosphide followed by Aluminium Phosphide

Data Analysis according to 3x3 factorial design revealed the method being differently effective in different seasons with highest mortality in rainy season followed by summer and winter seasons. Similarly the census baiting method was highly effective in rainy season, live burrow count in summer and % trap success in winter.

Bromadiolode and Brodifacoum

Bromadiolone reduced 61.2% rodents and brodifacoum 92%. Statistical analysis revealed bromadiolone being more effective during summer and winter while brodifacoum was more effective in winter and rainy season.

Potentiated anticoagulants

Ibuprofen potentiated bromadiolone reduced rodents by 89% while phenyl

butazone potentiation resulted in 80% mortality of rats. Brodifacoum potentiated by phenylbutazone caused 90% mortality and when potentiated by ibuprofen reduced 80% rats.

7. Reproduction Biology

i) The South Indian gerbil, *T. indica cuvieri* were found to exhibit a marked seasonal reproductive cycle. The peak reproductive activity was seen during October, November and December as the climatic factors of high rainfall and low temperature appear to favour the availability of food in the environment. During April till early August, mature gerbils were found to be in anoestrous period. Correspondingly, the accessory reproductive organs of male and female gerbils show seasonal changes in weight and also histologically. The litter number of implanted embryos ranged from 3 to 7 with an average of 6. The prevalence of pregnancy was 0.08 during April and 0.71 during November. The prenatal loss of embryos of gerbil was not a very common feature to account for the embryonic mortality. The analysis of population structure of these gerbils showed an increase of juveniles (body weight 10-45 gm) during early September onwards and a maximum of 55% during January due to intense breeding activity. On over all basis the ratio between male and female gerbils was not significant but fertile females were more than fecund males and none of the females weighing below 100 gm body weight were pregnant. During non-breeding summer months, adult gerbils showed lesser body weights. The annual productivity of gerbils was calculated to be 53 young per female per breeding period. It is concluded that April, May, June and July (Summer months non-breeding phase) period is the best suitable time for initiation of rodent control operation to achieve better cost benefit ratio.

ii) The lesser Bandicoot Rat, *Bandicota bengalensis* : Bandicoots exhibit an active reproductive phase during August to May (80%) and a decrease breeding activity during late May onwards. During these periods, the gonads and the accessory reproductive structures showed seasonal changes both in weight and histologically. The peak reproductive activity was evident during the months of September, October and November. The environmental factors of high rain fall and low temperature seemed to favour the breeding intensity of these bandicoots, during monsoon months. The litter size ranged from 3 during May to 11-12 during October and December with an average of 7.5. The prevalence of pregnancy was 0.07 during April and 0.85 during October. Though unilateral implantation was common, there was no preferential distribution of embryos between the uterine horns. The phenomena of superfoetation and embryonic mortality may not be a uncommon feature in bandicoots. The annual productivity of bandicoots was calculated to be 67 young per female per breeding season. The ratio between male and female bandicoots was not significant. Male bandicoots generally exhibited heavier body weights when compared with their counterparts.

It is recommended that the May-July (summer months, non-breeding phase) is the best suitable time for initiating rodent control programme in the fields to achieve better cost benefit ratio.

(iii) The soft furred field rat, *Rattus meltada* : The percentage of fertile metad population rise from the month of June (27%) till November and December (74%). The fertile metad weigh 60-70 gm and their ovarian weight ranges from 10 mg to 18 mg.

Pregnant metads were encountered during the months of July to January and the peak pregnant population was seen during the month of October and November (70%). Pregnancy was not recorded during February and onwards. The prevalence of pregnancy ranged from 0.25 during July to 0.69 in November. The litter number of implanted embryos ranged from 1-9 with an average of 4. The unilateral implantation was uncommon. The corpora lutea formed after the ovulation were distinct.

The percentage of fecund metad gradually increase from June (20%) till end of December and January (76%). The fecund metad weigh between 60 to 95 gms in body weight and their testicular weight ranges from 1.2 to 1.4 mg. Though the scrotal pouch was not distinct in fecund meltads, sperms were evident in the cauda epididymis. The other reproductive accessaries namely seminal vesicles, prostate glands exhibited secretary activity. The testes of immature metad weighed 190-270 mgs at body weight 40 gm. Further observation during the other months of the year so as to follow up the annual reproductive cycle of these meltada is in progress.

(iv) The brown spiny mouse, *Mus platythrix* : Nearly 50 per cent of the fertile females were recorded during the month of November and December. During January as low as 13 per cent of fertile females were collected. Their population increased till December followed by decline in their per cent occurrence. Fertile females weighed 50-68 gm body weight and their ovarian weight show a range of 10 to 18 mgs.

Pregnant females were recorded only during the months of July to December with a peak occurrence of 60 per cent during September and October. Pregnancy was not seen during January onwards though 4 per cent of them were found to be conceived during March. The prevalence of pregnancy ranged from 0.11 during March to 0.66 during September. The litter size varied from 2 to 7 with an average of 4. Bilateral implantation was very common feature and the ovary showed distinct corpora lutea formed after the ovulatory process.

The occurrence of fecund males followed almost a similar pattern of their counterpart. A peak population of 58 per cent was recorded during December. The fecund males weigh 50 gm and above and the testicular weight is 400-450 mg. The sperms are also evident in the cauda epididymis. The sex accessory glands of reproduction

were also active and showed secretory nature. The testes of the immature males weighed 120 to 250 mg and their body weight was less than 40 gm.

v) The greater bandicoot, *B. indica* : The adults weighed between 3 50-550 g. In females, the ovaries were distinct, glandular with follicles and ranged 19-89 mg. in weight. The coiled oviducts weighed between 5-10 mg. The uterus was thin, slender and weighed between 50-100 mg. The adrenals were equal in size and ranged 44-83 mg in weight. No pregnant females were represented in the above samples.

8. Rodent Pest Management in Cardamom

8.1 *Major Rodent Species that inflict cardamom :*

Rodent species trapped in cardamom cropped area in and around Mudigere Chikkamagalur district, Karnataka include *B. bengalensis. B. indica, R. rattus, Rattus meltada, Tatera indica, Mus booduga, Funambulus palamrum* and *Funambulus sublineatus. B. bengalensis* during night and *F. palmarum* during the day were the principal species of rodents damaging the crop.

8.2. *Damage* :

Rodents were observed to prefer 110 days old cardamom capsules. However rodents damaged greenish yellow capsules of 90 days to the extent of 20%. This is the stage when protection measures are warranted. The possible factors for preferential damage by rodents are due to the 'typical cardamom odour' emnating from matured capsules which contain mucilagenous matter, which is being easy to split. The cardamom crop grown in plains suffered more damage, 12.47% than that in slopes (1.40%).

Rodents in addition to feeding were found to hoard cardamom seeds. Examination of 130 burrows revealed that *B. bengalensis* hoarded cardamom capsules and the amount hoarded varied from 5.5 to 11.5 g fresh weight/burrow during November. The losses in yields varied from 8.70 to 12.60%. On an average, rodents incurred 10.50% losses in yields each year, amounting to, at the existing rate, for every 100 kgs of cardamom a loss of about Rs. 3000/- (Rupees three thousand).

8.3. *Control measures* :

The trap operated plot recorded 8.17% clump damage compared to 4.9% clump damage in non-trap operated area and there were no significant differences between the two sites. Our observations have shown that systematic trapping only temporarily reduces the population of rodents in cardamom ecosystem.

8.4 *Cultural Practices :*

Under natural conditions, the panicles are dispersed and capsules are exposed to rodent depredation. If the panicles are overlapped, few capsules may escape

from depredation. To test this, field experiments were laid out at BRS, Mudigere and at Hugluralli, Thirtahalli during 1989-1991. Clear cultivation (removal of weeds) and timely picking of capsules are the other two cultural practices that were evaluated against rodent damage in cardamom. Three years data on the impact of the three cultural practices on rodent damage revealed that by proper weeding (clear cultivation) on an average 3.57% loss can be avoided, by over lapping panicles at regular intervals 2.95% damage and by timely picking 6.63% damage could be avoided. Panicles of 25 cardamom clumps were covered by leaf mulch so that capsules were invisible to the rodents. Panicles of neighbouring clumps were left uncovered to serve as control. On an average, the leaf much covered plot recorded reduced rodent damage on capsules to an extent of 2.49% compared to 41.72% in the control. There was statistically significant reduction in capsule damage. Since the experiment was conducted on a small scale, it needs to be repeated on a large scale.

8.5. *Mechanical methods* :

Efforts were made to trap rodents using wooden snap trap. Before setting out the trapping grid, number of natural and preferred bait materials were evalauted in replicated trials. In wooden snap traps, only banana and paddy grains served as bait. Metallic traps proved ineffective in trapping rodents. Wooden snap traps proved effective in trapping squirrels especially at the commencement of the harvesting season, i.e., during August-September in Mudigere.

8.6 *Non-toxic chemicals* :

Fish oil, neem oil, extracts of cluster beans (*Phaseolus multiflorus*) and Bingo a non poisonous sticky substance manufactured by Rambo chemical Industries Pvt. Ltd. Bombay were tried. All the above non toxic chemicals proved ineffective in protecting cardamom from rodent damage.

8.7 *Toxic chemicals* :

5 g 100 g, Thimet + 5 g of dry sand were placed in punched polybags (15 cm x 5 cm) and suspended at the base of cardamom clumps to serve as repellent. The chemical proved ineffective in protecting cardamom from rodent damage. Although Rodacake and Bromadiolone baits offered some protection, nevertheless it failed to check the rodent damage which was observed in the treated plantations. Even after baiting, rodent damage was observed in the treated plots. Quintox (0.75%) and Storm (0.005%) baits also proved ineffective. Two gm each of the above four baits were placed 1 bait/station 50 clumps. The experimental site was atleast 0.25 km away from control site.

9. Social Engineering Activity on Rodent Control

9.1 *Phase 1* :

i) *Area :* Cultivated fields spanning about 2000 acres were elected near Kanakapura, 60 km away from Bangalore for this research project. It included seven villages namely Kallahalli, Adanguppe, Anumanahalli, Virupasandra, Baradanahalli, Malgal and Budiguppa. Throughout the area paddy is cultivated extensively during kharif. Whenever irrigation by subsoil water is possible paddy, pulses and ragi are grown during summer. About 5% sugarcane and 5% coconut plantations are maintained perennially.

Under this programme, about 600 acres of fields were divided into three units namely (1) *Survey area :* where no rodent control measures were taken up but population was censused regularly (2) *Maintenance area* : Both cultivated fields and residential premises in the villages were subjected to intensive poisoning regimes twice a year i.e. summer and kharif. The field pests were killed by zinc phosphide baiting followed by aluminium phosphide fumigation. The commensal rodents were poisoned with rodafarin baits. Population census was carried out prior to and after each control operation. In addition the levels of population were measured two months after each killing. The methods were by live burrow count and trap index in the fields and by per cent trap success in the houses. Species composition was determined by trap lines using snap traps in the fields and wire mesh live traps in the houses. (3) *Neglected area* : here as per the project outline intensive rodent control measures were taken only once i.e. at the beginning of operation but extension and education were carried out extensively. The population was censused from 1982 to 1985 as in the other two areas.

(ii) Rodent population fluctuation in fields : Maximum population density was seen before the first killing operation, i.e. during December 1982 in all the three areas. The population level of both maintenance and neglected areas remained lower to that of survey plots throughout the project period i.e. from December 1982 to June 1985. Between neglected and maintenance area, the former had a slightly higher level of population except during the months of March to June 1984 and February 1985.

Maintenance area : *B. bengalensis* was the major species through 1982 to 1984 prior to control. However the relative abundence of other species changed. In 1983 the species composition was *Bb* > *Rm* > *Mp* and in 1983 it was *Bb* > *Rm* > *Mb*> Ti and in 1984 only *B. bengalensis* remained as sole surviving species. *Neglected area* : In 1982 the relative abundance was *Bb*> *Mp*> *Rm* but in 1983 only *B b.* was found prior to control. After control the residual population comprised of 67% *Bb* and 33% *Mb*. In 1984 the order or occurrence was *Bb*> *Rm* > *Mb* prior to control but 100% Bb after control.

Survey area : The relative abundance of species was *Mb* > *Bb* > *Rm* in 1982, *Bb* > *Mb* > *Rm* 1993 and *Bb* > *Mb* in 1984. However a month after in 1983 only *Ti* was seen and in 1984 only *Bb* remained.

iii) *Population fluctuation of commensal rodents* : The level of commensal rodent population estimated as per cent trap success was higher for the survey region except for September and October 1983 and June 1985. In the maintenance area the rodent numbers were lower except during March 1983 to September 1983 and October 1985. The population of neglected area was lower than survey area except during August 1983, but higher than in maintenance area except during June 1983 to November 1983 and November 1984.

(iv) *Efficacy of rodent control operations* : The reduction in rodent population effected by rodafarin baiting was highest in the maintenance area throughout the experimental period except during summer of 1984 when the population in the survey area had a higher natural decline compared to the decrease effected by poisoning, which is hard to explain. The one killing operation carried out in neglected village kept the pest population at a lower level upto June 1984. i.e. about 18 months Thereafter the rodent population increased rapidly in this area. In contrast the pest population in the survey area exhibited two drops in November 1983 and November 1984 and a peak in June 1984.

v) *Cost-Benefit ratio* : The sustained campaign of rodent eradication in crop fields over the 3 year period of social engineering gave cost benefit ratio of 1:30 during kharif and 1:18 during summer if the labour cost is excluded and 1:22 in kharif and 1:13 during summer if laboures are hired for poisoning and censusing.

9 2 *Phase-2*

(a) *Area* : Three villages namely, Shanaboganahalli as Maintenance area; (2) Chokkanahalli as Neglected area and (3) Budamanahalli as survey area about 30 kms away from Bangalore were selected for this project. In this study area dry lands usually had borewell and hence the crops were grown under protective irrigation. Depending on the water yield vegetable crops were raised continuously in addition to horticultural crops like guava and coconut.

(b) The field operations were carried out during summer and kharif each year and each operation included pre-control, control and post control rodent population censuses. During the pre control rodent census in fields three census methods were adapted. They include (1) live burrows count/ha (2) bait census (gbait/station/day and (3) % snap trap index.

A few modifications were made during the study (1) Bait mixture of Ragi broken rice and jowar was replaced with mixture of ragi and broken rice only (2) Zinc phosphide poisoning was followed by 0.005% bromadiolone wax blocks. This was followed due to low moisture availability resulting in ineffectiveness of aluminium phosphide treatment (3) Providing poison bait in plastic covers was given up

as this was creating problems of mis-use among villagers thereby causing the death of non-target species.

(c) In houses rodent census was estimated by live trap and bait census (bait stations) methods. The commensal rodents were given anticoagulants namely bromadiolone 0.005%. Special emphasis on extension and education on rodent pest management to the farmers was also included in the programme. Evaluation of extension work was undertaken to assess the impact of social engineering activity.

(d) *Findings*

(i) *Species Composition* : *Maintenance village* (Shanaboganahalli); The predominant species was *R. meltada*. Except during 1991 when it was replaced by *B. bengalensis*. *B. bengplensis* was second in abandance followed by *M. platythrix* and *S. murinus*. Occurrence of *F. palmarum* was noticed during 1988 and did not re-occur during the study period. *T. indica* replaced *Suneus murinus* during 1991 from fourth place and was found only during 1991.

Neglected village (Chokkanahalli) : *B. bengalensis* was the predominant species in neglected village. Except during 1990 when *R. mettada* replaced *B. bengalensis*. Occurrence of *T. indica* was observed during 1991 only as in maintienancevillage. Such change in species composition could be due to replacement by migration after the elimination of major species. *M. playthrix* was observed during 1988 and 1989 and later it was not found.

Survey village (Budamanahalli) : *T. indica* was the most predominant and *R. maltada* replaced it during 1990. The other species was *R. meltada* followed by *M. playthrix*. Except during 1989 *M. booduga* was recorded only during 1987. *B. bengalesis* was observed during 1989 and 1991 and infact it occupied second rank replacing *R. meltada* abundance during 1991.

(iii) *Reduction in Rodent population consequent to intensive killing during 1987-1991*. Rodent population showed fluctuations during the study period. Control operations mainly resulted in the reduction of their populations in fields of maintenance and neglected villages. But later on their populations increased frequently in Neglected area/ village. Survey village showed normally an increase in population. The reduction was higher in summer compared to kharif which may be due to low population and non availability of food in dry lands since single crop was cultivated in dry lands.

Reduction as estimated by LBC/HA method

Per cent reduction of rodent population as evaluated by LBC/HA method showed higher reduction of 90-91% during summers of 1987 to 1989 comparatively

of lower reductions i.e., 59.58% during 1990 and the reduction further increased to 80% in 1991 in maintenance village. In neglected village, higher reduction was achieved during kharif 1987 compared to summer of 1987 and 1989. During 1988, 1990 and 1991 the population increased in neglected village, maximum being in 1991.

In survey village where no control operation was undertaken their population fluctuated and showed an increase during kharif 1987, 1988, 1989 and 1991, summer of 1988 and 1989. The population decreased during summer 1987 (50%) and 1990 (28.75%), indicating a natural decline in population which could be due to migration.

Reduction as estimated by Trap Index Method :

As this evaluation is based on rodent getting trapped, the results varied compared to LBC/ha method. No reduction was achieved during summer 1987 in Maintenance and Neglected village and during kharif 1987 in survey village. Population reduced totally during kharif 1987 and summer 1988 in maintenance and neglected villages respectively. Percent reduction was higher during 1989 to 1991 in maintenance village whereas a marginal reduction was seen during 1988, 1989 in neglected village of indicating their population increase by 2.55 folds in neglected village and 1.28 folds in survey village.

Reduction as evaluated by Active Bait Consumption Method :

Summer results were higher as compared to kharif in this method of evaluation during the study period of two years indicating lack of food availability as the factor responsible for higher reduction during summer control operations. This method have scope for ambiguity in results due to non target consumption, (ants, etc.) hence was discontinued after two years.

(iii) *Mean Percent Effective Rodent Control Success* : Effective control success in maintenance village was achieved during the study period of 1987-1991 and maximum success was during 1989. Control success was higher in maintenance village with active guidance and supervision compared to neglected village, where farmers did control on their own.

Neglegence by farmers and timing of operation was the cause for low control success in Neglected village. In 1990, population shooted upto to 148.84 per cent as compared to over 70 per cent reduction in village with supervision. Negetive success was observed in maintenance during kharif 1989 which could be due to migration immediately after control operation due to lacuna in spatial distribution. The results of population reduction in maintenance village is significant when compared with population increase in neglected and survey villages.

(iv) *Commensal Rodent Population Control*: *R. rattus* and *B. indica* are the species recorded in houses. Bromodiolone wax cakes resulted in mean 68% reduction in population in maintenance village during the study period. The maximum reduction of 85.1% was achieved during 1987. In later years, reduction of their population was comparatively less. This could be due to low levels of population after initial control. Neglected village showed 63.5% reduction during 1987. Whereas-commensal population fluctuated in survey village with an increased trend except in 1988 and 1991.

(v) *Impact of Social Engineering Activity*: The results indicate a steady improvement in awareness compared to their previous knowledge of rodent control; rodent species and on infestation and damage in maintenance and neglected villages. This was achieved mainly due to night meetings, person to person contact and discussion with farmer on their fields about the rodent damage, 74.7% and 66.6% of the population are fully aware and self sufficient over the knowledge of rodent control in maintenance and neglected villages, respectively. Inquisitiveness of farmers in survey village helped in achieving 50% of population learning about rodent control and rodent species. The impact of supervision in the categories of rodent control, rodent species knowledge on infestation and damage etc. can be seen from the results in three villages. But accepting to adopt rodent control technology significantly varied with farmers of maintenance village when compared with neglected and survey villages. Farmers were more willing to continue rodent control and adopt it in their farming practices. Neglecting i.e. only one time doing rodent control with active supervision and after wards not motivating farmers had severe draw back on accepting and adopting rodent control technology in farming practices. Thus consistent supervision over a period of few rodent control operations is absolutely essential. This factor has to be taken into account while further conducting social engineering activity on rodent control.

(vi) *Cost Benefit Ratio* : Analysis of the damage caused by hoarding of grain and cut tillers by rodents in cereals resulted in an estimated loss of 59 kg/acre. The mean reduction in rodent population was 71.04% resulting in overall grain savings 35.5 kgs/acre. Cost of operation including bait, zinc phosphide, bromadiolone was Rs. 8.0/acre. Thus a ratio of 1:18 with out labour and 1:9 with labour was arrived. In the fields with continuous cropping under protective irrigation, the damage was intense especially in cucumber fields, thus yielded a ratio of 1:30 without labour and 1:12 with labour..

(vi) *Conclusion* (a) *Control operation* : Under dry land situations, zinc phosphide (2%) need to be followed by bromadiolone (0.005%) wax cakes instead of aluminium phosphide. Further, the control operations in the fields due to zinc

phosphide registered 71.04% reduction of rodent population (the range being 55 to 86%). Bromadiolone cakes reduced population by 68%.

(b) *Time of operation* : Yearly two control operations, one during summer and the other during kharif especially in preharvest stage of the crop is ideal/recommended to maintain the rodent population at a low level, thereby reducing the actual crop loss for better harvest.

(c) *Rodent population census* : Live burrow count (LBC) and snap trap index methods seems to be ideal population estimating methods than active bait consumption method.

(d) *Cost : Benefit ratio* : The cost : benefit ratio of killing rodents in dry lands is 1:18 without labour and 1:19 with labour. Further in fields with continuous crops, the figures are 1:30 without labour and 1:12 inclusive of labour.

(e) *Farmer's response/awareness* : The impact of social engineering activity on rodent control among farmers as evaluated by a questionaire indicated a steady improvement in awareness as compared to their previous knowledge on rodent species, infestation and control aspects.

Extension programmes : Consistent supervision over a period of few rodent control operations is absolutely essential in motivating the farmers to adopt rodent control technology in their routine farming practices. Since only one time supervision and motivating the farmers of the Neglected area/village had severe draw back on accepting and adoption of the rodent control technology.

Central Plantation Crops Research Institute Kasaragod

The Kasaragod centre was sanctioned by ICAR during Fifth Five Year Plan. The Centre started functioning from July 1982 under the Division of Entomogy of the Institute with the following mandate :

1. Survey, collection and identification of rodent pests of the region,
2. Behavioural sudies on rodents associated with plantation crops,
3. Assessment of rodent damage to the plantation crops,
4. Reproductive biology of rodent pests of plantation crops,
5. Evaluation of existing and newer rodenticides with particular reference to baiting medium,
6. Management of *R. r. wroughtoni* and *F. tristriatus* in coconut groves and cocoa mixed plantations and
7. Social engineering activity on rodent control.

The research findings of the Centre from 1982 to 1992-93 are summarsed below :

1. Species composition of rodent Pests

1.1 *Coconut* :

Several species of rodents viz., rats, squirrels, bandicoots, gerbils and porcupines have been identified to damage coconut at every stage of cultivation. Among them, the black rat, *Rattus rattus* which is primarily responsible for tender nuts damage is considered as major pest. Four different sub species of *R. rattus* are so far identified to damage coconut. Of them *R. r. wroughtoni* is reported from mainland and *R. r. andamansis*, *R. r. holechu* and *R. pulliventer* are reported from Andaman islands. Coconuts orchards in Laccadive Islands are mainly inhabited by *R. rattus*. The bandicoots (*Bandicota bengalensis* and *B. indica*) and porcupine (*Hystrix indica*) were reported to damage shed nuts in fields on mainlands. These burrowing rodents along with Indian gerbil, *Tatera indica* also damage coconut seedlings in nursery. Flowers of coconut have also been reported to be damaged by western ghat squirrel, *Funambulus tristriatus*.

1.2 *Cocoa* :

The species identified to damage cocoa crop are *R. r. wroughtoni*, *F. tristriatus*.

F. palmarum. Other rodents found in association with this crop are *R. r. rufescens*, *R. meltada*, *Mus booduga*, *Vandeleuria oleracea*, *B. bengalensis*, *B. indica* and *T. indica*.

1.3 *Areca-Cocoa mixed habitats* :

Such mixed habitat at Hirehalli (Tumkur district, Karnataka) were found to be inhabited by wroughton's rat (46.9%) and *F. palmarum* (32.9%) followed by *V. oleracea*, *M. booduga*, *T. indica* and *R. r. rufescens*, *R. r. wroughtoni*, has been found to be major pest of cashewnuts and oilpalms. The white tailed wood rat, *R. blanfordi* was recorded for the first time to damage cashew nuts.

2. Spatial distribution of rodents in cocoa gardens

Studies at this centre reveal that *M. booduga* and *T. indica* were active only at the ground surface, whereas, *V. oleracea* on the branches. *F. tristriatus* and *R. r. wroughtoni* were principally arboreal but also foraged on the ground level to some extent. *R. r. rufescens* was active both at the ground as well as on the branches of cocoa trees. Out of 259 rodents collected from cocoa gardens, *R. r. wroughtoni* and *M. booduga* constituted more than 75% of total population on the ground level and were considered to be predominant in this particular microhabitat. Similarly, *R. r. wroughtoni* predominated the branches with more than 65% of total catch there (Table 1).

Table 1. Spatial distribution of Rodents in cocoa gardens.

Species	Location of trapping		Total
	Branches	Ground	
R. r. wroughtoni	95 (65.07)	15 (13.27)	110 (42.47)
R. r. rufescens	8 (5.48)	7 (6.19)	15 (5.79)
F. tristriatus	15 (10.27)	2 (1.77)	17 (6.56)
T. indica	0 (—)	2 (1.77)	2 (0.77)
V. oleracea	28 (19.18)	0 (—)	28 (10.81)
M. booduga	0 (—)	87 (76.99)	87 (33.59)

Note : Figures in parenthesis are % of the total in each column.

3. Assessment of damage

3.1 *Coconuts* :

Assessment of rodent damage to coconut has been carried out in Mainland, Andaman and Laccadive Islands. The damage in these locations was found to be 20,

35 and 55% respectively. The damage intensity to coconut was more when certain inter crops are cultivated along with coconut as compared to solo crop of coconut. Three year data on damage in Kerala indicated seasonal variation in rat damage to tender coconuts. The intensity of damage was more in summer and early monsoon (Aug.-Oct). In another study, in a 1.5 ha coconut orchards, the number of damaged nuts were recorded every month. Number of nuts damaged per month varied from 17-125.

3.2 *Cocoa* :

The intensity of damage to cocoa by rodents is very alarming. As high as 60% damage has been reported. In South Kanara district of Karnataka and in Kanyakumari district of Tamil Nadu, the damage reached upto 47.6 and 50% respectively.

3.3 *Other plantations* :

The oil palms have been found to be damaged by rats to a tune of 45% to nursery seedlings and 50% to oil palms. Damage by ***B. bengalensis*** to cashew nuts and its hoarding in burrows is very alarming. In one instance as many as 145 nuts were collected from the burrow systems of lesser bandicoot rat. Studies on extent of damage to cashew by *R. blanfordi* revealed that on an average 5.7 nuts were gnawed open and eaten by this rat per day.

4. Feeding behaviour of rodents

4.1 Coconut :

A typical rodent damage to tender nut was identified by presence of small hole (5 cm dia) near perianth region initially. After gnawing the husk the rats consume the inner contents. The damaged nuts usually remain on the bunch for 2-6 days before falling on the ground.

4.2 Cocoaa :

The cocoa feeding behaviour in rodents is an acquired characteristics developed by trial and error growing or immitating other experienced animals feeding on pods. Our observations indicate that squirrels damage the cocoa pods in the centre whereas rats damage near the peduncle. That is how the damage by the two species can be distinguished in the field.

4.3 Stomach content analysis of R. r. wroughtoni :

This study was conducted to understand the food habit of Wroughton's rat in the field. Stomach contents from 43 trapped rats indicated presence of 25 different types of food materials originating from 15 plants and 10 animal sources. The male flowers of coconut were most common in terms of quantity (41%) and fre-

quency of occurrence (65%). Cocoa, tender coconut husk and shell, grass seeds, small ants, grubs certain insects were found often. Mossa, fruits of *Physalis minima* and oilpalm, coconut kernel, beetles, roaches, caterpillars etc. also formed a part of their diet occasionally.

5. Ecobiology of rodents

5.1 *R. r. wroughtoni* :

It is an arboreal pest having nearly 82% of its activity on the tree canopy and makes the nests on the crowns of the palms. The nests weigh 100-200 made up of dry leaves and twigs. The males and females move in an area of 662 and 558 sq. m. respectively. The reproductive biology of this rat was studied in Minicoy islands and mainlands. The study revealed that rats in the body weight range 100-140 g predominate (20.7%) population. Sex ratio was more towards females. The mean prevalence of pregnancy was 21.3% (maximum 46.5%). Highest prevalence of pregnant females is observed during low rainfall periods (September-October), whereas, it is lowest during monsoon (June-August). Mean litter size by embry count was 5.92. The mean weaning period of the young was 35 days. It breeds throughout the year but with two peaks, one during early summer (February-March) and the other during mansoon (July-August).

5.2 *F. tristriatus* :

It is an omnivorous rodent having diurnal habit and bimodal feeding and activity pattern i.e. one peak in the morning (7.30 - 9.30 A.M.) and the other in the evening (3.00 - 4.30 P.M.) In the adult squirrels, the sex ratio was more towards males (59.3%) but females were represented in equal proportions (49.3%) in sub-adult, The sub-adult females are more in number during January, February, April-November and December. This squirrel breeds all the year round with peak during the summer season from December to May. The number of pregnant/lactating females was rather low from June to August (the period of heavy rainfall). The annual prevalence of pregnancy was 13.3% with a mean litter size of 2.5. Cannibalism. has also been reported among these squirrels.

5.3 *M. booduga* :

Preliminary observations revealed that the sex ratio of the mice in the plantation crops is evenly balanced, However, an overall percentage of males was 52.7%. Sub-adults occurred throughout the year. The prevalence of pregnancy was less during December-May. The litter size varied from 2-8. The litter having five embryos occurred more frequently.

6. Home range and population turnover (*F. tristriatus* and *R. r. wroughtoni*)

The studies on home range of squirrels and rats revealed that on an average one squirrel covers an area of 0.6 - 0.8 ha whereas one rat covers only 0.056 - 0.066

ha. Maximum distance which a squirrel and rat can travel was worked out to be 154-207 m and 46.2-48.8 m, respectively.

In the field, the rats attain maturity within 3 months of their emergence from nests. On an average, 50% of the population of rats and squirrels disappear from the population within 4 and 5 months respectively. The maximum survival of a rat was observed to be 12 months in fields. However, the squirrels survive longer than rats, i.e., for more than 20 months.

7. Bait preferences and shyness

Laboratory studies on bait preferences of *Mus musculus*, *M. booduga* and *V. oleracea* were made by multiple choice tests. The results indicated that cracked rice and wheat are preferred most by *M. musculus* and *M. booduga*, respectively. Both these species did not show any choice for oily or sweetened baits. However, *V. oleracea* preferred sweetened baits over to plain baits, with higher preference for cracked rice. The Wroughton's rat also preferred (2% sugar) rice grains, whereas, *F. tristriatus* preferred whole wheat grains. In another study with *F. tristriatus*. the test animals showed significant preference to rice for first 6 days. The preference for rice was maintained further also even when the place of feeding bowls were interchanged with other baits. This evidently reflect that these squirrels don't exhibit neophobia towards feeding bowls.

Bait shyness in *F. tristriatus* was evaluated in laboratory using rice and wheat. After sub-lethal poisoning with zinc phosphide (0.025%) on the preferred bait i.e. rice, the squirrels shifted their preference for wheat on first day itself. This behaviour (shyness) persisted for 7 days.

8. Rodent management :

8.1 Evaluation of trap efficiency :

Three traps viz., sherman, wooden box and wooden trap were evaluated for their efficacy in cocoa garden. The trap success was more with box traps (Table 2). *R. r. wroughtoni* and *R. r. rufescens* were trapped more in box traps, whereas, *M. booduga* in sherman.

Table 2. *Success of different traps in cocoa garden*

Species	Type of traps and trap days		
	Box	Sherman	Snap
R. r. wroughtoni	2.61 (51.08)	0.86 (16.83)	1.64 (32.09)
R. r. rufescens	0.16 (57.14)	0.04 (14.29)	0.08 (28.59)

F. tristriatus	0.12	0.11	0.08
	(38.71)	(35.48)	(25.81)
V. oleracea	0.78	0.68	0.25
	(45.61)	(39.77)	(14.62)
M. booduga	0 08	1.73	0.08
	(4.23)	(91.53)	(4.23)
Total :	3.82	3.42	2.13
	(40.77)	(46.50)	(22.73)

Note : Percentage of total trap success for each species given in parentheses.

In another study, live wire mesh single catch trap was reported to be very effective for the control of *F. tristriatus*. The squirrels were observed to enter the trap several times in capture-recapture study. This indicated that squirrels were not trap shy. Rice-coconut kernel were found to be ideal bait and September-October months are ideal for control operation against the squirrels.

8.2 *Laboratory evaluation of rodenticides* :

Several rodenticides have been evaluated for their efficacy against predominant rodent pests of plantation crops. In a study with first generation anticoagulants, warfarin and fumarin against *R. r. wroughtoni* no significant difference in their toxicity was observed. The IFP 50 value calculated was around 4 days for both the toxicant. The days to death varied from 3-12 days with warfarin and 3-14 days with fumarin. Among second generation rodenticides bromadiolone, brodifacoum, flocoumafen and cholecalciferol have also been evaluated in laboratory.

The lethal dosage for bromadiolone for cent percent mortality of Wroughton's rats was 1.25 mg/kg. In nochoice tests, bromadiolone wax cake (0.005%) exposed for 1 and 2 days yielded 100% mortality of test, rats with a death period range of 3-13 days. In choice tests, (Table 3) the rats did not show any aversion towards bromadiolone mixed baits. About 40% rats preferred poisoned baits. 43.3% preferred plain baits and 16.7% consumed both the baits equally.

Table 3. Choice feeding tests with plain and bromadiolone cakes on *R. r. wroughtoni*

Exposure days	Mean daily bait intake		Preference (%)		
	Plain	Poison	Plain	Poison	Neutral
1	3.30	2.30	40.0	40.0	20.0
2	2.75	3.74	50 0	40.0	10.0
3	3.85	2.05	40.0	40.0	20.0

In another study, brodifacoum and bromadiolone (0.005%) feeding resulted in 100 and 75% mortality of *R. r. wroughtoni* in one day exposure. The respective days to death ranged between 3-13 (bromadiolone) and 3-10 (brodifacoum). Cholecalciferol (0.075%) baits resulted in 10, 30 and 60% mortality of *R. r. wroughtoni* after an

exposure of 1,2 and 4 days, respectively. The acceptance of this poison bait was rather low i.e. 12 % of test rats did not prefer the bait. However, acceptance of this bait by *F. tristriatus* was very poor because 62.5% test squirrels did not consume the bait. The remaining test animals recorded 66.7% mortality after 4 days exposure. Toxicity trials of liquid brodifacoum (0.005%) with *F. tristriatus* revealed that as low as 1 ml of the liquid poison was lethal to them. The death period ranged from 3-12 days. In choice tests, both plain water and liquid brodifacoum were consumed in equal quantities In *R. r. wroughtoni* one day feeding of brodifacoum and flocoumafen resulted in cent percent mortality, whereas with bromadiolone 93.3% mortality was achieved.

In another study on acceptability of baits, it was found that the *F. tristriatus* did not accept baits in wax formulation. Towards acute poisons, the squirrels developed bait shyness on the very first day of exposure. On the other hand, black rats were observed to consume wax baits in appreciable quantities. Towards acute poison, these rats unlike squirrels, developed shyness only after 2-3 days of exposure.

8.3 *Screening of attractants*:

Sun dried ripe jack fruit carpels and banana were screened for their attractiveness against squirrels (*F. tristriatus*) under choice tests. Both these materials did not show and superiority over rice grain baits. However, in another trial with coconut water, cashew, apple essences and some synthetic essences revealed that coconut water was most preferred.

8.4 *Field testing of rodenticides :*

Field studies have shown that Wroughton's rats could be effectively controlled by multi dose anticoagulants. Warfarin and fumarin were found effective against the rats if they are exposed three times. One round of baiting with 105 g wax blocks per palm resulted in 53.5% reduction in damage. By repeating the poison baiting for two more times with 70 and 35 g baits respectively, at an interval of 3 days the damage was reduced to 100%. In coconut-cocoa gardens 30 such bait points are required in one ha plot (Table 4). In an earlier observation 61.4% control success was achieved in coconut orchards of Minicoy islands.

Table 4. Efficacy of warfarin cakes against *R r. wroughtoni* in coconut fields

Baitings	No. of damaged nuts		% success
	Pre control	Post control	
Once	63 5	29.5	53 5
Twice	23.5	7.0	70.2
Thrice	21.5	Nil	100.0

Among second generation anticoagulants, bromadiolone (0.005%) and brodifacoum (0.005)% baits have been evaluated. Both the anticoagulants performed

better (more than 70% control success) in coconut fields at Minicoy Islands in comparison to warfrain (61.9% success). In one of the trials with brodifacoum wax blocks following pulse baiting in cocoa gardens resulted in over 90%control of rats and 50% control of squirrels. The baiting was done three times at an interval of 10 days, when bromadiolone cake (0.005%) wax blocks was evaluated on 45 rat infested coconut palm. Two baitings at an interval of 18-20 days was done at the rate of 10 g bait per palm. The results revealed an overall control success of over 82% (on the basis of number of infested palms) and 79.6% (on the basis of number of damaged nuts). In another study, bromadiolone (0.005%) was found to yield a control success of 78.2% in coconut (Minicoy Islands) and 84% in cocoa (Kerala). Similarly, brodifacoum produced 75.5% control success in coconut (in Minicoy) and 95% in areca-cocoa system in Kerala.

9. Technology Transfer

Project scientists and Technical Officers conducted several field and apex level training programmes on rodent pest management in plantation crops covering the participants from Kerala; Tamil Nadu, karnataka States. Visits to Andaman, Laccadives Islands and Mainland were also arranged for field demonstration of rodent management techniques. Besides these, regular farm advisory services were also given to the farmers of plantation crops.

Central Arid Zone Research Institute, Jodhpur

1. The study area and the rodent problem

Jodhpur Centre is the founding centre of the AICRP. The Project was intiated in October 1977 with the objective to study the ecology and management of rodent pests infesting various agricultural, horticultural, grasslands and forestry plantations. Some of the salient findings of this centre are detailed here.

The study area of this centre is Rajasthan desert. This desert is perpetually scarcity biome. Rodents constitute one of the largest mammalian group in the Rajasthan Desert. They exhibit a great plasticity in respect of their choice of a wide spectrum of desert habitats. Rodents aggravate the problem of desertification by depredating upon the sparse vegetation and disturbing the soil through their fossorial propensity. Their role in intensification of desertification may be understood by the fact that a single species, *Meriones hurrianae*, is able to excavate about 61,500 kg of stabilised soil per km^2 per day during summer and deposit it outside its burrow openings in a loose formation. This loose soil is easily blown away by strong desert winds. Thus, rodents are a prime factor for soil erosion. Their impact on desert vegetation, orchards, crop fields and rangelands, as a result of their gnawing, debarking, cutting and feeding potential is easily discernible throughout the tract. Due to their sheer numbers and omnipresence in all the desert habitats, rodents are considered a serious pest problem and no desert development programme can be successfully launched without their management.

2. Rodent species

Three families of rodents inhabit the Indian desert biome. The species are :

(a)	Family Hystricidae :	(1) *Hystrix indica* Kerr
(b)	Family sciuridae :	(2) *Funambulus pennanti* Wroughton
(c)	Family Muridae	
(i)	Sub-family Gerbillinae	(3) *Tatera indica* (Hardwicke)
		(4) *Meriones hurrianae* (Jerdon)
		(5) *Gerbillus nanus indus* Thomas
		(6) *Gerbillus gleadowi* Murray
(ii)	Sub-family-Murinae	(7) *Vandeleuria oleracea* (Bennett)
		(8) *Rattus rattus* (Linn.)
		(9) *R. cutchicus* (Wroughton)
		(10) *R. meltada pallidior* (Gray)
		(11) *R. gleadowi* Gray
		(12) *Mus musculus* Linn.

(13) *M. cervicolor* Hodgson
(14) *M. platythrix* Bennett
(15) *M. booduga* Gray
(16) *Golunda elloiti* Gray
(17) *Nesokia indica* (Gray & Hardwicke)
(18) *Bandicota bengalensis* (Gray)

3. Ecological Distribution

3.1. Habitat Preference :

A great degree of habitat specificity has been noticed in the rodent species of the Indian desert. Habitat preference of rodents in Rajasthan desert in four distinct habitats viz., sandy, gravel, rocky and ruderal habitats have been studied. Some rodents occur exclusively in a particular habitat, such as *G. nanus indus* in sandy habitat, *R. cutchicus cutchicus* and *M. cervicolor* in rocky habiat and *M. musculus* and *M. booduga* in ruderal habitat. Other rodents inhabit more than one habibat, but based on their frequency of occurrence in large numbers in a certain habitat, these rodents may be assigned a particular niche (Table 1).

Table 1 : Habitat perference exhibited by the rodents in Indian desert

Sandy Habitat		Rocky habitat	Ruderal habitat	
Sand dunes	Sandy plains		Residential areas	Crop fields
G. gleadowi	*G. n. indus* *M hurrianae and R. gleadowi*	*H indica indica* *R. c. cutchicus* *M. c. phillipsi* *M. p. sadhu*	*F pennanti* *R. rattus and M. musculus*	*T. i. indica* *R. meltada pallidior* *M. booduga* *G. ellioti gujerati* *N. indica indica and* *B. bengalensis*

For example, *M. hurrianae* and *F. pennanti* may be assigned to have greater preference for sandy and ruderal habitats respectively though they occur in several other habitats also. Similarly, *G. gleadowi* and *R. gleadowi* prefer sandy habitat; *T. indica, R. meltada pallidior* and *G. ellioti* prefer ruderal habitat and *M. platythrix sadhu* prefer rocky habitat. Of these 4 rodent species share rocky and sandy gravel and ruderal habitats; 6 species share sandy and gravel habitats; 5 species share gravel and ruderal habitats; 4 species share rocky and ruderal habitats and 7 species share sandy and ruderal habitats.

The mode of living and various adaptations play an important role in selection of a particular habitat. The squirrel, *F. pennanti*, is an arboreal rodent and makes

nest from cloth rags, human hairs and leaves etc. The trees in desert are more in number near village complexes. It has therefore accepted the habitat near human habitations i.e. ruderal habitat and to some extent on hillocks where trees are found in some numbers. *G. nanus* and *G. gleadowi* prefer sandy habitat because of their ability to withstand water shortage and drifting sands. *G. gleadowi* makes shallow and simple burrows on the loose sand dunes from which it can find its way out in the night hours even when these are buried under blowing sands.

In the sandy habitat *M. hurrianae* (60% frequency) and *T. indica* (28.8% frequency) occur mainly on the foot hills of stabilized dunes or interdunal spaces, where they can dig extensive and deep burrows. However, most preferred habitat of *T. indica* is near village complexes and cropfields, i.e. ruderal habitat, probably because of its higher water requirement than that of *M. hurrianae*.

The Cutch rock rat, *R. c. cutchicus* is found in appreciable numbers in fissures and crevices in the rocks, whereas on the slopes, where some sand accumulates, the porcupine, *hystrix indica indica* makes its burrows.

The ruderal habitat is a complex habitat having two main sub-habitats viz., homesteads or residential areas, and crop fields. *R. rattus* and *M. musculus* are found in houses. *T. indica*, though a field rodent occurs quite frequently in the vicinity of houses in Bikaner city. The cultivated fields are favourite habitats of several species of rodents, viz., *T. indica*, *R. meltada pallidior*, *Mus booduga*, *Nesokia indica* and *B. bengalensis*. *M. hurrianae* are found on the borders of crop fields from where they feed on crops, the squirrels, *F pennanti* occupy the trees scattered in the crop fields and *G. ellioti* prefer the thickets of bushes.

During last 50 years Rajasthan desert is witnessing a great change because of increasing cropping practices. When the sandy plains are converted into cropfields, the merion gerbils migrate out, due to mass destruction of their complex burrows and establish on the fringes of crop fields. When the crops are harvested these gerbils again colonise the crop fields and the threshing areas.

3.2. Relationship with Soil Types :

Three major soil types are recognised in the desert with regard to rodent distribution viz., dune soils, desertic soils and red and yellow soil. The duny soils are sandy and are found in the northern district of Rajasthan. This soil is inhabited by *G. gleadowi*, burrows of which have been observed even on mobile sand dunes, In the red desertic soil, commonly found in parts of the Pali, Jodhpur, Nagaur and Bikaner districts, the most abundant rodent species are *M. hurrianae* and *T. indica*. The red and yellow soil are found along the foothills of the Aravalli ranges and are mainly represented in parts of Pali, Jalore and Sirohi districts of Rajasthan. This soil type is inhabited by *G. ellioti gujerati*, *M. platythrix sadhu*, *M. cervicolor* and

R. *meltada pallidior*. In the irrigated soils whether irrigation is through canals or dug wells. *N. indica*, *R. meltada pallidior*, *Mus booduga* and *G. ellioti* are the common rodent fauna. The relative abundance of *M. hurrianae* in relation to soil types has also been extensively studied. It has been concluded that the clay percent in soil and number of desert gerbils. have inversly proportional relationship. Their population is very low in the duny soils of western Rajasthan and irrigated fields of Sri Ganganagar district. But in the Central and South eastern districts of Rajasthan where the soil is red desertic, the desert gerbil is more abundant proving that this type is most suitable for them.

3.3 Relationship with Vegetation Types

The rodents of the Indian desert are fairly versatile in regard to their association with various vegetation communities. None of the rodent species is particularly associated with any plant type. Thus a single plant species can not be regarded as an indicator of a rodent species. Some broad associations however, have been established, *Mus cervicolor phillipsi* is always trapped on rocky outcrops under the bushes of *Haloxylon salicornicum*, *Eupharbia caducifolia*. *Rattus c. cutchicus* always fonnd on hilly outcrops having the dominant grass, *sehima nervosum*. Well drained sandy soils where *Cenchrus setigerus*, *C. ciliaris* and *Lasiurus sindicus* are the common grasses. are inhabited by the four gerbils. The only rodent inhabiting the sand dunes, *G. gleadowi* is mostly associated with *Panicum antidotale* and *Citrulus colocynthis*.

M. hurrianae is more abundant in the communities having *Aristida* spp. as a predominant grass. It was also found that the desert gebils shift their burrows near *Citrullus colocynthis* when it fruits. In the 100 mm rainfall areas of Jaisalmer district, these gerbils were found to be associated with the perennial bush, *Haloxylon salicornicum*. There is no specific correlation between vegetal cover and the rodent population.

3.4 Relative Numbers

An overall view of various habitats show that *M. hurrianae* and *T. indica* are the most abundant rodent species in the Indian desert. Others which follow are, *R.m. pallidior*, *R.c. cutchicus* and *G. gleadowi*, Other rodent species are represented comparatively in low numbers. Following sequence of rodent abundance in different habitatsis have been recognised.

1. In sandy habitat : *M. hurrianae* > *T. indica* > *G. gleadowi* > *R.m. pallidior.*
2. In gravel habitat : *M. hurrianae* > *T. i. indica* > *M.p. sadhu.*
3. In rocky habitat : *R.c. cutchicus* > *M. p. sadhu* > *M. c. phillipsi* > *F. pennanti.*
4. In ruderal habitat: *T. i. indica* > *R. m. pallidior* > *M. hurrianae* > *G. gleadowi* > *F. pennanti.*

3.5 *Population Fluctuations*

The seasonal fluctuations of rodent population have not been extensively investigated on a long-term, year to year basis, but some information on this aspect is available for the predominant rodent species (Table 2). The trapping data on *F. pennanti* indicated a gradual decrease of its population from April to October. But in case of *T. indica* a broad pattern of monthly fluctuation was noticed. The merion gerbil, *M. hurrianae* has been reported to show a population buildup during winters which continues till spring and then their number declines during summer. The data on other rodent species did not record any particular trend but bimonthly collections revealed uniform catches for *R. m. pallidior* and maximum catch of *M.c. phillipsi* and *M.p. sadhu* in July and March, respectively.

Table 2 : Monthly fluctuation in the number of various desert rodent species.

Rodent species	Fluctuation in the numbers											
	Jan.	Feb	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct	Nov.	Dec.
F. pennanti	—	—	—	102	54	61	36	47	28	30	10	6
T. i. indica	30	39	51	53	63	69	55	74	78	42	40	43
M. hurrianae	—	—	300	—	—	131	—	170	—	—	—	385
R. c. cutchicus	—	—	49	—	26	—	47	15	—	32	—	23
R. m. pallidior	—	—	12	—	10	—	12	0	—	10	—	—
M. c. phillipsi	—	—	15	—	11	—	21	0	—	2	—	15
M. p. sadhu	—	—	21	—	9	—	11	1	—	1	—	—
G. e. gujerati	—	—	4	—	4	—	5	1	—	1	—	—

An overall comparison of seasonal fluctuation of predominant species revealed that (i) their number is lowest during the hot summer months due to hostile living conditions in the desert and (ii) the population buildup is during spring and soon after the monsoon. These two population build up periods coincide with that of highest breeding activity among desert rodents. The two peaks are of great significance since at these periods, the kharif and rabi crops are at flowering/maturity stage when the ruderal rodents cause havoc in the crop fields.

3.6 *Food*

The desert rodents are mainly phytophagous and feed on almost all parts of plants and seeds. Some of them even feed on insects during summer months when the vegetation in the desert is scarce. The food of certain rodents has been studied in detail. Squirrel, *F. penannati*, being a commensal rodent largely depends on kitchen

waste in the towns but the squirrels inhabiting orchards and other trees feed upon seeds and fruits of trees, such as *Prosopis cineraria*, *Acacia senegal*, *Grewia tenax*, *Azadirachta indica*, *Zizyphus* sp. pomegranate, grapes, guava and vegetable crops causing severe damage to fruits and vegetable crops. They have also been observed to consume insects. The gerbils, *T. indica Indica* and *M. hurrianae* feed upon grasses, shrubs and trees. The stomach contents analysis of these two gerbils revealed that both the gerbils feed on maximum quantities of seeds during winter. The rhizomes and stems are found upto 40-45% of the total food in the stomachs of merion gerbil during summer but it is less than 20% during winter. In case of *T. indica indica*, the proportion of rhizome and stems fluctuates between 15-30% all the year round. During monsoon and post-monsoon season, these gerbils relish leaves and flowers.

4. Losses due to rodents

The rodent population being high in the desert and their demand for food being unsatiable, these pests maintain an appreciable pressure on the desert grassland, rainfed and irrigated crops in particular and on the other plant communities in general. The rodent poulation influence the critical ecological balance in the desert by their changing mode of feeding with seasonal availability pattern of various food items in nature and thus become an important component of the desert ecosystem. They comprise perhaps the largest group of primary consumers also. Due to their very large numbers, the rodents play havoc with the vegetation wherever they are and attain a status of pest for the farming community.

4.1 *Losses to grassland and fodder crops* :

Whenever seeds of *C. ciliaris*, *C. setigerus* and *L. sindicus* are sown in the grasslands to improve the fodder quality for better animal production, rodents dig them up and feed on them almost to the roots of the fodder. The intake of grass seeds by *M. hurrianae* is much greater than by other rodents feed upon the unripe inflorescence of grasses and when unable to reach them, they gnaw at the base of the plants. Field rodent devastated some 40 acres of *L. sindicus* and 27 acres of *C. ciliaris*, *C. cetigerus* and *L. sindicus* in an experimental pasture at Bikaner. These grabils prefer grasses which are relished by sheep and other desert livestock. At a population level of 477 gerbils per ha in a range management area, it is estimated that the feed requirement of the gerbils is about 1040 kg/ha whereas the total productity of this grasslond was only 1210 kg/ha, which mean that almost nothing was left for the livestock. This estimate does not include the wastage of green vegetation that the rodents indulge in, which would be about eight times the amount required for feeding. Because of the rodents, preference for nutritive and highly palatable grasses and other edible plants, the nature of the original plant communities in the Indian desert has totally changed to non-productive and degenerated vegetation type. Due to their continuous feeding several grasses have been replaced by less productive annuals, like *Aristida* spp., *Tephrosia purpurea*, *Cyperus arenarius*, *C. rotundus* and

Cenchrus biflorus which are the characteristic vegetation of degraded ranges. In addition to these, rodents are also serious inhibitors of the process of plant regeneration due to their seedivorous nature. All these factors in their turn affect the establishment of good pastures for the livestock industry which largely depends on the grasslands.

4.2 *Losses to forest plantations* :

Rodent damage to tree species, particularly young saplings is of two types (1) debarking and (ii) slicing. The debarking type of damage has been observed in *Albizzia lebbek*, *Prosopis cineraria*, *A. tortilis* and *Parkinsonia aculeata*. This activity is restricted above the ground surface and may also extend to the lateral branches. Usually the bark alongwith the cortical cells of the stem are damaged with detrimental effect on tree growth. The debarking activity has been observed in 3-4 year old trees. Further it is reported that the debarking activity is done mainly by *M. hurrianae*, *T. indica* and *R. maltada*. Obervations indicated that these rodents debarked *A. tortilis* and *P. aculeata* plantation upto a height of 13.6 and 11.6 cms, respectively.

Several trees are also seen to have been completely cut by rodent resulting in the death of the trees. This type of slicing activity has been noticed from the "bets" of the Great Rann of Kutch also. The occurrence of *Nesokia indica* from a 25 ha forest plantation range in Nagaur district, which was particularly responsible for slicing activity from underground resulting in the death of 4.4,10.0 and 10.0 per cent plantatations of *A. nilotica P. juliflora*, *A. nilotica*, respectively. Similar type of damage to tree plantations by rodents in sand dune fixation areas has also been noticed.

4.3 *Losses to fruit crops* :

Fruit orchards are not exempted from rodent attack. Rodents eat or spoil the fruits. Squirrels are the major pests of *ber*, guava and pomegranate. Squirrels caused total loss of 29% of ripe pomegranate fruit in 1988-89. *M. hurrianae* and *T. indica* have also been observed to feed on *ber* fruits. Their burrows in *ber* orchards during the fruiting stage ranged between 600-791. per ha.

4.4 *Losses to field crops* :

The desert rodent inflicts severe losses to the standing rainfed as well as irrigated crops from germination upto harvest in the fields and later in the threshing yards and stores. Squirrels and gerbils have been noticed to eat even the sown seeds before germination. The losses are further aecentuated at the seedling stage by the the rodents viz., *F. pennanti*, *T. indica* and *M. hurrianae*. In Rajasthan, *G. gleadowi* proved most destructive for sown seeds of bajra crops, An upsurge in population of *T. indica* was noticed during 1989 kharif in Rajasthan which resulted in serious losse to *bajra*, *moth* and *moong* crops. The *bajra* crop is most relished by these

gerbils at the milking stage when they feed upon the cob by felling the plants. When the *bajra* crops, are heaped in the threshing floor, after harvest, the gerbils follow the cobs, dig tunnels under them and feed upon the *bajra* grains leaving cobs near their burrow openings. Similarly in chillies *T. indica M. hurrianae* and *R.m. pallidior* complex damaged 15-20 kg of fruits per day per ha at a population density of 142 burrows/ha which resulted in damage of about 40.0% fruits/plant. These rodents were more serious at the peripheral areas of field. In mustard crops the rodents reduced 22.9-43.5% plant stand in the peripheral areas of crop fields at a burrow density of 73.1/ha. Similar studies in vegetable crops revealed 4.1-19.9% rodent damage in 12 commonly grown crops (Table 3),

Table 3 : Extent of damage and yield losses due to rodent pests in vegetable crop in a desert village complex.

Vegetables	Mean + S.E. percent damage (mean of 2 years)		Mean yield (q/ha)			Yield ratio (experimental/control)
	In experimental area	In control area	In experimental area	In control area	Reduction in yield	
Tomato	1.0 ± 0.43	19.0 ± 2.59	141.0	121.0	20.0	1.16
Brinjal	0 6 ± 0.26	4.5 ± 0.31	136 0	125.5	10.5	1.08
Carrot	3.5 ± 1.20	15.8 ± 1 23	147 0	128.5	18.5	1.14
Sweet potato	0.1 ± 0 08	4.3 ± 0.89	149.5	128.5	21.0	1.03
Raddish	2.0 ± 0 50	19.8 ± 0 85	145.5	124.5	21.0	1.16
Cabbage	0.2 ± 0 31	7.1 ± 0 45	249.0	236.0	13.0	1.06
Cauliflower	0.5 ± 0.41	5.5 ± 0.11	198.0	189.0	9.0	1.05
Onion	0.7 ± 0.41	8.8 ± 1.29	228.5	220.5	8.0	1.04
Garlic	0.5 ± 0.32	6.6 ± 0.05	101.0	95.0	6 0	1.06
Spinach	0.5 ± 0.21	4.7 ± 0.09	64.5	62.0	2.5	1,04
Bottle gourd	0.5 ± 0.16	4.1 ± 0.10	306.5	300.0	6.3	1.02
Okra	0 6 ± 0.22	4.4 ± 0.16	111.0	107 0	4.0	1.04

Note : In experimental area rodent control operations were done twice in a year (i.e. before sowing *kharif* and *rabi* crops).

5. Reproductive biology

The informations compiled for a variety of desert rodents are detailed in Table 4 and 5.

5.1 *Gerbillus sp.* :

Both the species occurring in the Rajasthan desert, viz,. *G. n. indus* and *G. gleadowi* have two breeding seasons in a year i.e., winter and summer. High prevalence of pregnancy is noticed during May-June and October-January for *G. gleadowi*. A small litter size of 2-3 is recorded for *G. n. indus* whereas the latter species showed comparatively larger litter size in winter (5-6, Av. 5.5) than that in summer(2-4; Av. 2.75).

5.2. *T. indica indica* :

It is observed that this species breeds all the year round with percentage of

females found pregnant varying from 9.7-61.0%, the annual average being 29.7%. Peak breeding activity was observed during February, July-August and November. The litter size of *T. indica indica* in the desert varied from 1 to 9. A litter size of 5 occured most frequently.

5.3 *M. hurrianae* :

This gerbil also breeds round the year. The data on the prevalence of pregnancy indicated that females have three breeding peaks in a year, viz; during February to April, in July and during September to November, while the rate is low during December and January, the severest winter months in this desert.

5.4 R. cutchicus cutchicus :

Highest prevalence of pregnancy occurs during August and nil during December. During March and May the occurrence of pregnancy was slighly higher but it declined considerably in July which was rather paradoxical, because all other desert rodents studied showed highest breeding activity in July. It had a litter size of 2-8 with an average of 4.0 young ones per female.

5.5 *R. gleadowi* and *G. ellioti gujerati* :

Pregnancy in *R. gleadowi* was observed from August to October with a litter size of 2-3 (av. 2.3), whereas in case of *G. e. gujerati* pregnant females were observed during March to August with embryo number varying from 5 to 10, the average being 6.6.

5.6 Rattus rattus rufescens :

Observed prevalence of pregnancy indicated that it had two breeding peaks, one in spring and the other during monsoon. The mean litter size of this subspecies was 5.69 (range 1-9).

Table 4, Peak breeding season and litter size of the desert rodents.

Rodent species	Peak breeding season	Litter size
H. indica	Monsoon and in December (In zoo)	1-3
F. pennanti	i. March to September	1-5
	it. March-April and July to September	
G. nanus indus	April, June and December	2-3
G. gleadowi	May-June and October to January	2-3 (Summer) 5-6 (Winter)
T.indica indica	February, July-August and November	1-9
M. hurrianae	February to April	1-9
R. c. cutchicus	March to May and July	2-8
R. gleadowi	August to October	2-3
G. e. gujerati	March-August	5-10
R. rattus	April-September	1-9
R. m. pallidior	Spring and Monsoon	—

Table 5. Per cent adult females found pregnant in the Rajasthan desert throughout the year.

Rodent species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
F. pennanti	0.0	31.7	70.0	31.2	32.5	16.2	42.5	17.5	10.0	0.0	0.0	0.0
T. indica indica	26.6	47.4	30.0	12.5	16.6	41.1	46.6	61.0	9.7	10.5	38.8	15.7
M. hurrianae	7.6	24.2	20.8	20.0	12.0	11.4	21.0	16.6	18.2	26.0	20.0	9.3
R. c. cutchicus	—	—	50.0	—	45.5	—	5.9	88.9	—	77.0	—	0.0
R. m. pallidior	21.0	51.5	99.0	75.0	62.5	55.0	100.0	100.0	100.0	83.0	33.0	31.0

A comparison of breeding season of desert rodents indicated that most rodents breed from March to September, although a few breed all through the year. Minimum births occur during the winter season and not during summers, when the conditions are largely unfavourable.

After passing through a partial quiescent period during the preceeding winter, their inherent, internal physiological mechanism are reactivated during the spring inducing a large number of them to indulge in breeding activity. This activity again declines during June. Yet suprisingly, some species continue to breed in the summer season also, The major breeding peak during the monsoon season corresponds with the availability of green food in plenty in the desert. Many desert plants flower and most of them produce fresh shoots and leaves in this season which might be an important factor in acceleration of their breeding activity.

6. Effects of irrigation agriculture on the desert rodents

Ecological relationship between rodent species composition and changing land use pattern in the canal command areas of Rajasthan desert having 60, 40, 20 30 and 10 years of intensive irrigation, has been studied. Major canal systems in Sri Ganganagar District of Rajasthan State (India) are Gang Canal (1927-28). Bhakhara Canal (1951-52) and Indira Gandhi Canal (1956-57). Irrigated cropping is practiced in about 80% of the area for varying periods. The remaining area is a typical desert having sandy plains and alkaline patches. Species composition and trap index revealed that the rodent population was highest in 10 year old irrigation cropping systems and minimum in the 60 year old irrigated fields. Two mesic species of rodents viz., *Rattus meltada pallidior* and *Mus musculus bactrianus* were found to inhabit 60, 40 and 30 years old irrigation cropping systems, whereas, two xeric rodent species viz., *Meriones hurrianae* and *Gerbillus gleadowi* were found only in 10 years old irrigation systems. This showed that the xeric rodents are being replaced by mesic species after about 30 years of intensive irrigation cropping system.

Besides these two mesic species, *Rattus rattus* and *Tatera indica* were also trapped from sugarcane and cotton fields during winter season. The fields had an irrigation intensity of 30, 40 and 60 years. The 10 year old irrigation areas also harboured *R. meltada* and *M. musculus* in sugarcane fields whereas in gram fields cultivated on the sandy plains true desertic species like *M. hurrianae*, *G. gleadowi* and

Rattus gleadowi were noticed in winter season. The areas with 30 and 10 years old irrigation recorded occurrence of *Suncus stoliczkanus* also which is rarely found in the desert ecosystem.

Similarly during summer season, *R. meltada pallidior* predominantly occurred in 60, 40 and 10 years old irrigation system. Besides this *T. indica* was also trapped in the crop fields with 60 and 10 year old irrigation intensities. *Suncus murinus*, the shrew also inhabited the crop fields with 60 and 30 year of irrigation status. Changes in land use pattern due to intensive irrigation through canal systems had resulted in "atavism" in the habitat as shown by presence of two common domestic mammals *M. musculus* and *S. murinus* in the crop fields with 30 or more years or irrigation practice.

7. Rodents as indicators of desertification

Studies on rodents as indicators for monitoring the desertification process have revealed that true desert adapted rodent species like *Meriones hurrianae* and *Gerbillus gleadowi* are absent from the Bharatpur, Agra and Mathura regions, suggesting there by that these areas have not yet been affected by the desertification process. It has been further observed that *Bandicota bengalensis* and *Mus musculus* have started invading the new ecological situations in Mahendragarh region in Haryana, where irrigation facilities have increased as a result of the opening of the Juhi Canal. Heavy infestation of *B. bengalensis* in wheat, mustard and gram crops, grown in the canal command area has been recorded.

Data collected in the Sri Ganganagar-Bikaner area on the infestation patterns of rodents in relation to period under irrigation viz. 50, 25, 15 and 5 years, have revealed that *Mus musculus bactrianus* and *Rattus meltada pallidior* are the two economically important rodents in the first three types of irrigation. On the other hand, the Indian gerbil, *Tatera indica* and the desert gerbil, *Meriones hurrianae* have been found in areas of 5 year irrigation records.

8. Scent marking gland

Ten economically important desert rodent species were screened for the presence of the mid-ventral scent marking gland. It was found in five species of rodents viz. *Meriones hurrianae*, *Tatera indica*, *Rattus meltada*, *Gerbillus gleadowi* and *G. nanus*. It was absent in *F. pennanti*, *G. ellioti*. *Rattus rattus*, *M. musculus* and *M. booduga*. In *R. meltada* the gland is present only in males while in *M. hurrianae* and *T. indica* both sexes posses the glandular pad.

Glandular area was found to be maximum in *R. meltada*, *M. hurrianae* and *T. indica*. A yellow oily secretion extracted from the gland was used for marking objects in the territory of the animals.

It has been observed that the size of glandular pad was correlated with the rodents' territorial behaviour and social hierarchy. The scent marking frequency of the dominant individuals was much greater than of those placed lower in the social hierarchy.

The length, width and area of the mid-ventral scent marking gland of *Meriones hurrianae, R meltada* and *T. indica* were found to be significantly ($P > 0.001$) and positively correlated with body weight, body length and age of the animals. The major function of the midventral gland appeared to be marking of burrow entrances and the pathways, the dominant males using it with a significantly more frequency than the submissive ones. Later, detailed work on this aspect was done under project of Eminence scheme.

9. Behavioural studies

Observations indicate that deprivation of water increases exploratory behaviour among *M. hurrianae* but food-cum-water deprivation does not seem to influence it. It appears that in *M. hurrinae* food intake gets priority over drinking water since the animals depend chiefly on the water contents of the food and on the metabolic water in their natural evironment-the desert.

10. Neophobia

A series of cxperiments were conducted on the Indian desert gerbil. *M. hurrinae* to observe their responses to new objects. These experiments were conducted in plus mazes. It is revealed that this wild species develops a marked aversion to new objects, new containers and new places during subsequent days. The neophobie behaviour usually persist for 2-3 days and may extend upto 8 days.

11. Phago-stimulant property of gland sebum and urine

Pearl millet (*Pennisetum typhoides*) scented with the odour of the Indian gerbil was consumed in significantly higher quantities as compared to ordinary feed by animals of this species. It appears that the secretion of ventral scent marking gland and tne urine odour act as phagostimulant in *T. indica*. However, no indication of an active role of the ventral scent marking gland in sexual activity of these rodents has been obtained.

Addition of 0.4% conspecific urine to food significantly ($P < 0.401$) enhanced its intake by both sexes of *M. hurrinac*. It has also been revealed that the addition of conspecific urine in poison baits makes the avoidance and bait shyness behaviour of desert gerbils. These finding have a practical significance in the sense that zinc phosphide can be used consecutively on a second day in the same field control sequence after mixing the bait with urine. This would increase the effectiveness of the control operation.

12. Bait preferences

Studies on bait preferences revealed that the rodents sample all food materials provided however, they may exhibit 'marked preference' for some baits and 'slight preference' for others and they can prefer more favourable of the two or even the most favourable among several bait materials. Such studies also provided information on the amount of food consumed by various rodent pests of arid areas in a single feeding which is helpful in determining the poison bait required at the time of their control.

In most of these studies, about 5-10 locally available foodgrains were provided singly and in multiple choice to individually caged rodents as whole grains, cracked grains, flours along with additives like vegetable oils, sugar and salt to determine their relative acceptability by these test animals. The most preferred bait materials emerging out from every such study are listed in table 6. Riec wheat and millet or pearlmillet are the three most preferred baits for the Indian rodents. These were followed by sorghum, maize and gram. Due to the versatility of the feeding habit, rodents readily change their preference from one bait to another, hence at least 2 or 3 preferred baits should be known.

*Table 6 : Most preferred baits and Calorific requirements of rodents.

Species	Preferred bait	Calorific requirement (Kj/100g/day
Funambulus pennanti	Whole wheat or craked bajra	104 87
	Millet grains or wheat grain	(67.63-146.21)
		(63.11-178.06)
Tatera indica	Bajra of sorghum grains	——
Meriones hurrianae	Wheat flour or Cracked bajra	150.48 (117.04-183.9)
Rattus rattus	Maize flour + 10% arachis oil + 1% sugar	121.80 (63.2-250.4)
Rattus meltada	Bajra flour + 10% sesame oil	(58.52-83.6)
Mus musculus	Pearlmillet or rice flour + 1% arachis oil	52.17 (145.08-372.2)
Golunda elloti	Wheat flour + 10% arachis oil + 1% sugar	90.49 (51.4-150.7)

The choice of baits is influenced by taste, texture, nutritional value of the food and the previous experience of feeding. Our studies reveal that *T. indica*, *M. hurrianae* and *R. c. cutchicus* prefer whole grains over cracked grains or flours. *G. gleadowi*, *R. meltada*, and *R. rattus*, liked flours or small particle-sized food rather than whole grains. Conflicting results are reported in respect of the consumption of oily foods. A few species consumed more bait with vegetable oil (*T. indica*, and *R. rattus*), whereas in *M. hurrianae*, *R. meltada* and *G. ellioti*, bait consumption declined due to the addition of oil. This may be due to increase in energy value of food item. To regulate energy intake, a reduced consumption of oily food is expected. Therefore

the role of additives like vegetable oils which have no distinct taste, is to adhere the poison particles on to the bait. Any vegetable oil which is locally available can therefore be used.

Addition of sweetening agents (sugar or saccharine) and salt have either no impact or a little effect on the consumption of bait material with preference to sugar over salt. It is generaly said that rodents (specially laboratory rats) prefer the food of high nutritional value. But this well known fact does not hold good with the field rodents. For example, oil enhances the nutritive value of food but some rodent species even lower their consumption of oily food. Likewise, some cereals of almost equal nutritional value have different rank in the preferential order. Moreover, field rodents may change their diet seasonally which depends upon the availability of food in their respective environment. It appears, therefore, that the acceptability of bait depends much upon its taste rather than the texture and nutritional value.

On the basis of amount of bait consumed, 2 groups of rodent species with body weight ranging from 20 to 140 g (field rodents) and 120 to 200 g (Commensal) have been identified. Food consumption among rodents largely depends on their body weight and varies from 7.8 to 21.1 per cent of the body weight. The daily intake of food by *R. rattus*, *T. indica* with respect to the per cent of body weight is 8 and 6 per cent. respectively.

13. Bait/Poison Shyness

13.1 Persistence of Shyness :

The phenomenon of bait shyness was studied against all the major rodents of arid ecosystem. Even a single exposure of sublethal dosage of zinc phosphide resulted in shyness behaviour (Table 7). This behaviour pessisted in the rodents for varying periods. The metad, *R. meltada* revealed highest (135 days) and the gerbil, *G gleadowi* recorded lowest (10-15 days). In another study, the five striped squirrel recorded as high as 104 days of persistence of bait shyness. The magnitude of shyness dependad mainly on amount of poison dosage consumed and the expossure period.

Table 7 ; Persistence of Zinc phosphide indcued bait shyness among desert rodents.

Spaces	Persistance of bait Shyness (days)
1. *Funambulus pennati*	30, 104
2. *Gerbrillus gleadowi*	10-15
3. *Tatera indica*	115
4. *Meriones hurrianal*	35
5. *Rattus rattus*	75
6. *Rattus meltada*	135
7. *Mus musculus*	20
8. *Rattus cutchicus*	75

13.2 Mitigation of Shyness :

Study on the effect of changing the bait, the oil, duration of poisoning and poison itself, to mitigate the bait shyness developed due to Zn_3P_2 in rodents were conducted at this centre. Secondly addition of conspecific urine or sebum exudates in the baits was found to mask shyness behaviour considerably.

14. Stomach Contents Analysis

Detailed investigaton on stomach content analysis was conducted on *T. indica* a major pest in this area. Observations indicated that the gerbil follows a seasonal preference for its food. During Summers rhizomes were preferred the most, in winter there was a clear prefrence for seeds and in monsoon, leaves and other plant parts frequented in higher quantities. There was clear preference for leaver of *Cenchrus ciliaris, Lasiurers sindicus, Cynodon dactylon* and *Prosopis cineraria*. The frequency of occurrence was higher for the leaves of *Ziziphus nummularia* and *P. cineraria* during winter. Stomach contents analysis of another gerbil, *G. gleadowi*, inhabiting sand dunes revealad occurrence of seeds of *Citrulus colosynthis* forming 40-60% of the total content.

15. Evaluation of Rodenticides

15.1. *Laboratory evaluation* :

During late seventies, acceptability of three acute poisons viz., Scilliroside (0.005%), RH-787 (1.0%) and Zinc phosphide (2.0%) was compared on five desert rodents. Of these RH-787 was most acceptable to the field rodents, whereas scilliroside was more acceptable to commersal rodents.

The LD_{50} of warfarin for *T. indica* and *M. hurrianae* was found to be 4x19 mg/kg and 4x15.9 mg/kg respectively. Feeding for 14 days on 0.025% warfarin treated bait provided complete kill among gerbils but the poison bait was less palatable than plain bait. A period of 18 and 19 days feeding on 0.025% warfarin bait was found suitable to detect resistance in case of *T. indica* and *M. hurrianae* respectively.

Another anticoagulant rodenticide, fumarin was evaluated on *T. indica* and *M. hurrianae*. The LD_{50} for both the gerbils was found to be of the order of 4 x 15.9 mg/kg. Feeding trials with 0.025% fumarin treated bait resulted in 100% kill in 14 days. The lethal feeding period to kill 50% (LFP_{50}) for *T. indica* and *M. hurrianae* was found to be 5.5 and 6.2 days, respectively. The poison bait was less palatable as compared to plain bait.

Racumin (hydroxycoumarin), another anticoagulant rodenticide, was evaluated to find out its efficacy for the control of *T. indica* and *M. hurrianae*. The LD_{50} for these species was found to be 4 x 0.60 and 4 x 0.53 mg/kg respectively. Feeding trials on individually caged gerbils with 0.0375% and 0.05% racumin treated pearl

millet grains resulted in 100% kills in *T. indica* after consecutive feeding of 5 and 4 days respectively. The difference between the lethal feeding periods to kill 50% animals was not found to be significant between sexes, species and concentrations. It may be concluded that although poison bait was less palatable than plain bait, this anticoagulant (Racumin) is effective at both the concentrations used.

An evaluation of the efficacy of brodifaccoum, a single-dose anticoagulant rodenticide, against *T. indica*, *M. hurrianae* and *R. rattus* has revealed that LD_{50} and its 95% fiducial limits for these species are 0.10 mg/kg (0.08-0.17 mg/kg), 0.083 mg/kg (0.05-0.13 mg/kg) and 0.77 mg/kg (0.40-1.28 mg/kg), respectively. Complete kill in *T. indica* and *M. hurrianae* was achieved after three days feeding; and after 4 days feeding in *R. rattus* with bajra grains containing 0.002% and 0.005% brodifacoum. This anticoagulant was found to be significantly less palatable ($P > 0.001$) than plain baits. At 0.002% concentration, this poison is recommended for the control of *T. indica*, *M. hurrianae* and *R. rattus* population. Similarly, 0.0075% of chlorophacinone, in the bait material can be used for the management of *T. indica* and *M. hurrianae* populations.

The relative toxicity of bromadiolone was also evaluated on *M. hurrianae*, *T. indica*, *F. pennanti*, *R. rattus* and *M. musculus*. It was found that toxicant at 0.005% result in more than 80% control succees against major rodent pest of the area. the LD_{50} values are 2.5 (*F. pennanti*), 0.11 (*T. indica*) and 0.55 (*M. hurrianae*) mg/kg, respectively.

Flocoumafen, a new rodenticide was also tested against all the predominant pest species of the region i.e. *M. hurrianae*, *T. indica*, *R. rattus*, *M. musculus* and *F. pennanti*. The posion proved very effective at 0.005% dosage against all the test species. The consumption of the posion bait was more than the plain bait in most cases. Even a lower conc. of 0.002% yielded 80-100% kill is no choice test. In choice tests, however, the mortality at various concentration was from 50-100%.

Another rodenticide, cholecalciferol, a vitamin D_3 based compound was also evaluated for its effectiveness against *R. rattus* and *T. indica* in two formulation viz., wax blocks and pellets. It was noticed that pellets were lesser acceptable than the wax blocks. The wax blocks yielded 89% mortality against Indian gerbils.

15.2. *Field Evaluation* :

Various rodenticides have been evaluated in crop fields, grasslands, horticultual crops, poultry farms and houses and godowns. Among acute poisons, zinc phosphide and RH-787 faired well. RH-787 at 1% concentration resulted in excellant control success in fields. The compound was later withdrawn on medical grounads. Zinc phosphide at 2.0 % conc. in cereal bait resulted in over 70% control success in crop fields. In the later years, anticoagulant rodenticides were field tested. Among first

generation anticoagulants, warfar in, coumatetralyl and chlorphacinone on multiple baitings yielded 96.6%, (in house) 66.9% and 0-72.4% (in grassland) control success, respectively.

In a field trial, bromadilone (0.005%) produced 70-80% control success in groundnut, cotton, moong, rice arhar and sugarcane crops fields in Rajasthan on the other hand brodifacoum (0.005%) produced 80-90% control success in the similar crop lands. The pest complex of the region was *R. meltada, M. hurrianae T. indica, B. bengalensis* and *M. musculus*. This rodenticide yielded 90.5% control sucess in fodder (grassland) crops inhabited by *M. hurrianae, T. indica, G. gleadowi* and *R. gleadowoi*. In the vegetable crops and fruit orchards, brodifacoum yielded 89 and 94% control success, respectively. Treatment of zinc phosphide followed by bromadiolone in *ber* orchards proved superior to either of the rodenticides in solo treatments. The rate of populatoin rebuild up was also very slow in the former treatment with two rodenticides.

16. Social Engineering Activity on Rodent Control

Rodent control operations involving farmers were taken up in several villages around Jodhpur during the last 15 years. It has been revealed that about 50-80 per cent of the farmers in these villages have adopted rodent control work as a regular agronomic practice. Results indicated that a 95 per cent reduction in field rodent population increases the wheat crop yield to the tune of 296 kg/ha, the cost benefit ratio being Rs. 1:247. In vegetable crops, the average losses due to rodents have been evaluated as 8.7 per cent. A reduction of 92.5 per cent in the number of field rodents corresponded with an increase in the production of vegetable crops to 11.7 g/ha, the cost benefit ratio being 1:900. Similar results have been achieved in the residential premises also. These long term studies taken up with the collaboration of the farmers have resulted in a number of findings of practical importance,

(a) Control operations at six monthly intervals, continued over 7 years, reduced field rodent population to 5 per cent of the initial level, corresponding to 95 per cent reduction in losses to agricultural production.

(b) However, if rodent control operations are not repeated after the initial operation, the population reaches the initial level within $1\frac{1}{2}$ years.

Punjab Agricultural University, Ludhiana

1. History and Mandate :

The Ludhiana Centre of the AICRP was sanctioned by ICAR during September, 1977 with a broader objective to evolve effective technology for the manage ment of rodent pests of Punjab region. The mandates of the Centre are :

(i) Survey, collection and identification of rodents in different ecological regions.

(ii) Laboratory and field evaluation of rodenticides.

(iii) Screening of sex attractants and antifertility agents and repellents for rodent management.

(iv) Cultural methods of rodent control.

(v) Reproductive biology of rodents.

(vi) Behaviour and control of rodents in poultry farms.

(vii) Grading rodent damage and estimation of economic threshold levels.

(viii) Rodent pest management in different irrigated crops of the Region.

(ix) Social Engineering Activity on Rodent control.

The achievements of this Centre during last 15 years are detailed as under.

2. Species composition and population fluctuations :

In Punjab, eight species of rodents are predominantly found in the fields, two species in the residential premises and godowns and one rodent species in the orchard.

In the fields, the population analysis has revealed the co-existence of *Rattus meltada*, *Mus musculus bactrianus*, *Mus booduga*, *Mus platythrix*, *Bandicota bengalensis*, *Tatera indica* and *Golunda ellioti*. In addition, *Meriones hurrianae* has also been reported from fields and waste lands in Sangrur, Faridkot, Bathinda and Ferozepur districts of Punjab. Also occurrence of short-tailed mole rat, *Nesokia indica* is reported from different parts of Punjab. In waterlogged alkali soils of Faridkot and Ferozepur districts only *R. meltada* was observed to withstand the salt stress and *B. bengalensis* had shifted to high bunds.

The fluctuations in the populations of murids have revealed that in the last decade, *R. meltada* was found to be the most abundantly occurring murid in

Punjab. Population of Indian mole rat was only about 10% of the reported murid fauna of economic importance. Due to changes in the agronomic practices and cropping pattern in Punjab, the major changes in murid populations have occurred. The bandicoot population has increased. This change in the population structure of rodents may be related to changes in agroclimatic condition related with increased paddy cultivation during recent years and the aggressive dominance behaviour of the rodent.

Survey of rodents was further continued in 7 more districts of Punjab. The lesser bandicoots were predominant in irrigated fields, whereas *T. indica* and *Mus* sp. were predominant in unirrigated fields. In the less irrigated sandy soils, *R. meltada* was the predominant species. In the central plains of Jalandhar and Ludhiana districts and north western parts of Ferozepur and Faridkot districts, the spcies composition is *B. bengalensis*, *R. meltada*, *T. indica*, *Mus* sp. *Golunda ellioti* in the order of predominance. In the semi-arid sandy areas of Bathinda district and sub mountaneous Kandi watershed in Hoshiarpur districts, *B. bengalensis* was not trapped.

3. Rodent migrations in relation to crops

In order to know whether the rats and mice inhabit the fields permanently or they disperse to the adjacent areas to attack the flourishing crops, bunds, water channels and pathways surrounding the crops were surveyed at each developing stage of the crop. The number of burrows of different murid species were counted both in the boundry areas and inside the crops by live burrows count technique.

The results indicated that the murids house and multiply for most of their life in the permanent boundaries of the fields as well as in the adjacent waste bunds. They spread inside the crops with development of crop, shelter and availability of food. The activity of the murids and hence damage is less inside the crops at seedling stage. The number of burrows inside crop fields start increasing as the crop matures and maximum activity of rodent inside the groundnut, sugarcane, paddy and wheat occurs at the maturity stage.

4. Burrowing pattern of *Rattus meltada*

The burrows of soft furred field rat are generally found in sandy, sandyloam. loam and light clay soil. 290 burrows were dug out in different crops. i.e., sugarcane, wheat, paddy and groundnut. Twenty burrows were dug out at each developmental stage and after harvesting. The burrows were dug out alongwith bunds and permanent pathways. In paddy fields, burrows were only excavated at maturity stage and after harvesting of the crop.

The burrows of *R. meltada* open to exterior by means of 1 to 3 surface openings. In some cases 1-2 surface openings are blocked with small quantity of soil and are temporarily out of use. Such openings may be used readily by rats in

case of emergency. The range of length and depth of the metad burrow has been recorded to be 25-512 cm and 27-65 cm, respectively irrespective of the crops and crop stages. Inside the crop fields maximum of of 218.27 ± 12.0 cm length of burrows recorded, whereas, alongwith bunds and permanent pathways, length upto 512 cm was observed. In majority of the burrows, nest chambers were present, an average being 1.5±0.8 bed chambers in each metad burrow measuring 17.5±10.5x 9.0±3.9 cm.

5.0 Food and feeding behaviour :

Feeding behaviour of five murid species was studied in detail with an aim to find out the suitable and most acceptable bait form to be used for preparing poison bait.

5.1 *Food and feeding behaviour of Rattus meltada* :

(i) *Food Consumption* : Soft furred field rat being a nocturnal murid consumes maximum food during the night. Practically, no significant difference ($P > 0.01$) in the mean daily intake was observed when the foods were offered in 'no-choice' or in 'choice' to the metads; the mean daily intake was 7.58g/rat/day in no-choice and 7.03 g/rat/day in choice. Defaecation rates were also lower during day time than at night; 21.41% of the feaces being eliminated when the foods were given one at a time and 18.40% when the food grains were given one at a time between 7.00 and 19.00 hours.

Overall weights were recorded when all the five test cereals were given separately. Highest weight gains were recorded when millet and rire or millet and maize cereals were provided in choice feeding. Weight loss were observed only when sorghum and rice and maize and rice cereals were presented to the rats in choice tests.

(ii) *Bait preference* : When cereals were given in no-choice to the metads, the consumption of wheat was recorded maximum followed by that of millet, sorghum, rice and maize. These cereals when tested in no choice, the rats preferred one of the two foods offered and the daily intake of the less preferred foods differered considererably ($P > 0.01$) In some tests, millet: sorghum and maize: sorghum, almost equal amounts of two foods were consumed and the daily intakes were not significantly different. This indicates their tendency to vary the diet of "omnivory" which is advantageous to the natural environment. But based upon total consumption, the metads generally selected foods in linear manner much like the Indian gerbil, *Tatera indica*. Wheat and millet were preferred ($P. > 0.01$) over all the other cereals in respective tests. Even then, the rats consumed the other alternatives available in small amounts. Thus they 'sampled' the available foods in every tests.

(iii) *Additives* : Various oils e.g. groundnut oil, conconut oil, mustard oil, sugar and salt were used to study their effect on food intake of soft furred field rats. To formulate a simple, effective and economical poison bait for local farmers in their

efforts to control field rodents, an oil is used as an adhesive. Rodents indicated that foods mixed with oils were significantly more consumed ($P>0.01$) than the ones withot oil.

Of the three different oil components tried in the diet, both in males and females diet containing groundnut oil(4%)and coconut oil (10%) was significantly less ($P>0.01$) consumed than that of the diets containing mustard oil (10%) in no-choice, choice and multipe chioce trials. Tasteless groundnut oil mixtures are as acceptable to soft-furred field rats as they are to other rodents.

Sugar as well as salt were also provided alongwith the test foods smerared with 2% groundnut oil. 1% sugar was preferred over 1% salt. The average daily intake of salt mixed wheat ($P>0.01$), millet ($P>0.02$) and sorghum ($P>0.01$) were significantly lower than that of sugar mixed test foods respectively.

(iv) *Texture preference* :

The metads were offered various cereals in three texture forms (whole grains, cracked grains and flours) in 'no-choice' and in 'choice' tests, The comparison of test foods both by 'no-choice' and 'chioce' trials indicate the acceptance of powdered and finely divided food forms over respective whole grain forms ($P>0.01$).

5.2 *Feeding behaviour of Bandicocta bengslensis* :

Indian mole rat, *B. bengalensis* daily consumes food equivalent to 4% to 7% of the body weight. It is a nocturnal rat and maximum feeding occurs at night.

To find out the most suitable bait form to be used for preparing poison baits, various food items were tried in bi-choice trials for fixed number of days.

(i) *Whole cereals* : Equal preferences were obscrved when sorghum was tested with millet and rice seperately. But sorghum was markedly preferred over both wheat and maize. Rice and millet were eaten in equal amounts, when offered. However, millet was markedly preferred to both wheat and maize. In the choice of rlce and wheat, rice was preferred significantly. Maize was not preferred overall. Among cereals and cereal flours maize flour was preferred over both the whole forms of maize and sorghum. In Sweet and oily foods the mixture of cottonseed oil and cane sugar were significantly consumed over the plain alternatives.

(ii) *Daily food intake* : Cereal flour and sweet foods were eaten in greater amounts than the whole cereals or oily foods. The total daily consumption varied from 4.05 g to 7.42 g/100 g body weight/day according to the various foods offered. The mean daily intake was 4.9453 ± 0.1945g/100 g body weight for the whole cereal combinations and 5.3143 ± 0.7933 cal./100 g body weight for various food offered.

Caloric intake varied from 14.3105 to 26.8693 cal./100 g body weight/day. The daily caloric intake was 18.7933 cal./100 g body weight for various foods offered.

The total mean protein and fat intakes were 0.4658 ± 0.0476 and 0.0988±0.0152 g/100 g body weight/day, respectively.

5.3. *Feeding behavier of Nesokia indica* :

The comparison of average daily food intake per 100 g body weight of rats revealed equal preference for maize flour, cracked wheat and wheat flour out of the 19 foods tried in no-choice feeding tests. These foods were markedly preferred (<0.01) overall others tested.

When whole and cracked forms of foods were offered in choice, the rodents consumed cracked forms in signficant ($P<0.05$) amount, exception being rice and groundnut seeds where both the forms were almost equally consumed. When the rats were offered flours in choice with cracked and whole forms, they consumed flours significantly more ($P<0.05$). However, two forms of millet and sorghum were taken almost equally in both the tests.

When various combinations of cereal flours were tested in no-choice by mixing two flours in equal quantities, maize flour mixtures were highly favoured by rats. The rats preferred oily and sweet foods more ($P<0.01$) than the plain alternatives. However, plain wheat flour was favoured ($P<0.01$) over salty food.

5.4 *Feeding behaviour of Mus platythrix* :

Four oils namely, mustard oil, coconut oil, groundnut oil and cottonseed oil were tested (2%) with the three cereals viz., millet, wheat and sorghum.

In no-choice trials millet was the most preferred food followed by millet-groundnut oil. The mustard oil with all the cereals proved to be the least accepted oil. Though, the millet-groundnut oil was the most acceptable food item after plain millet but its effect was not comparable with other cereals. Addition of oil in cereals disrupted the order of cereal preference. The results obtained suggest that groundnut oil, coconut oil and cotton seed oil can be used as adhesive while preparing poison baits.

In choice tests, addition of groundnut oil in the bait increased the total daily food intake in comparison to the same plain cereal, exception being sorghum grains. Oily diets having mustard oil were altogether rejected in all the tests. Even the least preferred cereal, sorghum was preferred over millet+mustard oil.

5.5 *Food consumption and preference of Funambulus pennanti* :

A known quantity of maize, gram, wheat, husked rice, sorghum, groundnut kernels, guava, banana, *ber*, apple, pea, carrot, radish, potato and cauliflower were exposed daily.

The MDI of maize, gram, wheat, husked rice, sorghum and groundnut per squirrel was 4.9, 7.6, 9.7, 9.9, 10.0 and 5.2 g/100 g of body-weight for sorghum. The

MDI of apple, *ber*, guava and banana was 56.9, 45.8, 23.2 and 23.2 g/100 g of body-weight of a squirrel respectively, whereas the MDI of vegetables were 68.3, 34.0, 17.6 and 18.9 g/100 g of body-weight of a squirrel for carrot, brinjal, pea and cauliflower respectively. Thus the consumption varied from 17.6 g/100 of body weight for pea to 68.3 g/100 g of body weight for carrot.

Observations on food preference reveal that husked rice was the most preferred food and its consumption was significant more ($P > 0.05$) than that of sorghum, wheat, maize and gram. When dry grains were supplied in different forms (whole grains, flour and roasted grains), it was found that the consumption of roasted grains was significantly more than those of whole grains and flour in the case of maize and gram, whereas the consumption of whole grains was more than that of flour and roasted grains in the case of wheat.

There was no significant difference in the consumption of apple and guava at 5% level of significance when the fruits were supplied simultaneously. However, the consumption of these two food items was significantly more than that of banana and *ber* ($P < 0.05$).

Among vegetables carrot was significantly more preferred ($P < 0.05$). However, there was no significant difference in the consumption of cauliflower, radish and brinjal. However, the squirrels did not touch potatoes.

6. Neophobic and neophilic behaviour

6.1 *Rattus meltada* :

It displays the typical new-object reaction but the extent of reaction varies greatly. Studies were conducted in a 'plus maze'. The presence of the novel objects in the food arm resulted in a marked decline in rats' activity in the arm. New objects reaction was elicited when the objects unfamiliar in appearance, odour and taste were placed in a thoroughly familiar area.

In experiment in which a single source of food was made available in 'plus maze', from which the rats were excluded by neophobia, the decline in avoidance (for one day) may have been hastened by starvation, as avoidance was prolonged to 2-3 days when two food sources were made available.

New place reaction was studied in the 'plus maze' by allowing the rats access to an arm which had been previously closed. The rats explored the new area mainly on the first day of exposure and the response thereafter declined (Day 8 < day 5, $P < 0.01$ for both visits and duration). The activity in the food and water arms was not affected. Although, the new areas provided no incentive other than the opportunity to explore. It was regularly visited each day, even when the rat got familiar to it but they spent little time in the new area.

6.2 *Bandicota bengalensis* :

Changing of food container had no effect on the daily intake of lesser bandicoot rats. All the adult individuals showed no interruption in daily consumptions. But in young rats (A_1, A_2, A_3) slight decrease in daily intake was observed after the change was made. On the basis of these observations it is concluded.

(i) That the adult wild rats explore repeatedly unfamiliar stimulus.

(ii) The young rats show avoidance of novel object for few hours, because of 'fear' (evoked by the effect of novel stimulus). That is why their daily intakes decreased a little).

(iii) The appearance of novel object (size, shape and smell etc.) may determine the period of exploration of avoidance.

(iv) The period of exploration or avoidance may depend on age and experience.

7. Feeding and baitshyness behaviour

Pen trials of multichoice food preference in a specially designed area of 3.84 sq.m. which provided enough opportunity of exploration revealed that *B. bengalensis* establishes a peculiar feeding pattern of exploration and sampling which did not affect its preference order. After sublethal ingestion of zinc phosphide (0.025%) the bandicoots displayed conditioned aversive response for 5-6 days which was reduced to 3-4 days when native partner of opposite sex was introduced. This indicates that the rodents mutually influence the feeding activities towards plain and toxic foods.

Baitshyness srudies reveaded that the persistence of shyness behaviour in *B. bengelensis* lasts for 65 days, if zinc phosphide treatment is done only once. In case of repetitive use of the same poison baitsyness may persist upto 475 days. In general 20% rodents develop shyness in one application.

8. Circadian rhythms

The studies on the circadian rhythms of rodents have been recorded considering behavioural patterns like eating, drinking, grooming, exploration and sleeping. Except sleep and rest, all other activities appear to be more during dark phase. Comparison of the percentage of the total activities have revealed marked difference between locomotion, exploration, miscellaneous activities (cage cutting and play) during the dark and light phases indicating that the rats spend relatively more time on these activities during dark phase. In comparison to dark phase period of sleep and rest was about four times in the light phase. Grooming activity was slightly more during dark phase (Table 1.).

Table 1. Comparison of behaviour activities of *B. bengalensis* during light and dark phases.

Behavioural activity	Activity per rat during light phase		Activity per rat during dark phase	
	Mean±S.E.	% of total activity	Mean±S.E.	% of total activity
Sleep and rest	153.48±5.07	33.99	63.86±2.40	10.75
Consummatory (Eating and Drinking)	28.45±1.55	6.30	50.07±1.68	8.55
Grooming (Licking, scratch&face washing)	81.97±4.69	18.15	117.62±7.34	19.80
Locomotion (walking and climbing)	48.30±2.71	10.72	97.28±8.69	16.38
Exploration (shiffing and seeing)	109.50±10.93	24.25	189.34±8.18	31.88
Miscellaneous (cutting and play)	29.81±3.25	6.60	75.03±13.2	12 63

9. Rodent damage

Estimation of preharvest economic loss revealed that per hectare loss due to rodent amounts to Rs. 287.00 in wheat, Rs.190.00 in groundnut and Rs. 409.20 in rice. It is estimated that annual rodent damage to these crops amounts to about Rs. 160 crores in Punjab state. The data from different districts of Punjab indicated tiller damage of 3.9-4.84% in wheat and 1.10-17.5% in rice and pod damage of 4.35% in groundnut. Rodents damage rice crop above the economic injury level is about 87.7% fields. In wheat presence of 2-3 active bandicoat burrows or rodent activity at 2-3 places per acre was found to be an indication for initiation of control measures.

10. Laboratory evaluation of rodenticides

Ten rodenticides viz. zinc phosphide, RH-787, silmurin, barium carbonate (acute toxicants); warfarin, coumatetralyl (multi-dose anticoagulants); bromadiolone and brodifacoum flocoumafen (single-dose anticoagulants) and cholecalciferol have been evaluated.

Brodifacoum at 0.005% concentration in one day no-choice and 2 days choice trials has resulted in absolute kill of the six species of rodents (Table 2 and 3). It has been found that of the daily total food requirement of *B. bengalensis* and *R. rattus* 10 to 20% of 0.005% brodifacoum bait was found sufficient for their absolute kill. Addition of 8% paraffin wax in the poison bait (0.005% brodifacoum) showed no significant effect on the bait consumption and the toxicity. The observations indicate that wax can be used for making the blocks or pellets of poison bait without affecting the acceptance and toxicity of the poison.

Bromadiolone bait at 0.005% concentration in rwo days 'choice' trials against *R. rattus* and three days choice trial against *B. bengalensis* resulted in 90% and 100%

success respectively (Table 4). Bromadiolone bait was acceptable to these rodents as no significant differenc in the intake of poison bait and plain bait was observed.

Table 2. Results of no choice feeding tests with brodifacoum against six species of rodents

Species	Mean bait intake (g)/100g body wt.		Mean intake of active	% morta-	Days to death Mean (Range)
	Pre-treatment of plain food	consumption poison food	ingredient mg/kg.	lity.	
Rattus meltda	16.3 ± 2.3	15.7 ± 1.9	8.1 ± 1.0	100	6.3 (4-10)
Rattus rattus	13.9 ± 1.0	12.5 ± 0 8	6.3 ± 0.4	100	9.2 (4-16)
Tatera indica	10.0 ± 1.5	7.7 ± 0.9	3.8 ± 0.4	100	8.4 (5-12)
Bandicota bengalensis	10.8 ± 0.9	14.2 ± 2.0	7.1 ± 1.0	100	7.5 (4-16)
Mus musculus	29.5 ± 1.4	31.5 ± 4.1	15.7 ± 2.0	100	9.6 (3-23)
Funambulus pennanti	N.R.	11.7 + 0.8	5.9 ± 0.4	100	4.6 (3-5)

Table 3. Results of choice feeding tests with 0.005% brodifacoum bait.

Species	Mean daily intake g/100g Body wt.		Mean intake of active	% Morta-	Days to death Mean (Range)
	Plain 'a'	Poison 'b'	ingredient mg/kg.	lity.	
Rattus meltada	6.23 ± 0.92	3.33 ± 0.75	1.66 ± 0.37	88 9	5.8 (3-10)
Rattus rattus	5. 5 ± 0. 4	5. 2 ± 0. 4	5. 2 ± 0. 4	100	7 7 (4-11)
Tatera indica	8. 6 ± 1. 8	5. 4 ± 1. 8	3. 8 ± 0. 9	100	7.2 (5-10)
Bandicota bengalensis	4. 9 ± 0. 4	3. 2 ± 0. 5	1. 6 ± 0. 2	90	10 (6-19)
Rattus rattus	10% 6. 9 ± 0.47	0.69 ± 0. 1	0. 6 ± 0. 7	63.6	6.6 (4- 9)
	20% 9. 4 ± 0. 8	1. 8 ± 0. 2	0.94 ± 0.08	90	9.8 (5-20)
Bandicota bengalensis	10% 14.2 ± 0 08	1. 4 ± 0. 1	0.44 ± 0.05	80	9.1 (5-11)

*Represent the amount of poison food as per cent of the total daily requirements of rodents (Calculated on the basis of 4-6 day pretreatment intake), offered to rodents on choice for one day.

Table 4. Efficacy of 0.005% bromadiolone bait against various murids.

Species	No. of feeding days	% morta-lity	Poison ingested mg/kg	Days to death Mean (Range)
No choice feeding				
R. rattus	1	85	3.5	5.8 (2-15)
	2	100	6.7	7.4 (5-11)
R. meltada	1	100	5.8	6.4 (5-8)
R. bengalensis	1	60	4.7	5.3 (4-7)
	2	90	7.0	11.3 (-23)
	3	100	14.4	10.4 (6-15)
Mus platythrix	1	100	11.3	5.8 (3-7)
Choice feeding				
R. rattus	2	90	2.43	7.8 (4-13)
R. bengalensis	3	100	.. ...	8.4 (5-12)

Coumatetralyl at 0.0375% concentration caused 100% kill of *R. rattus* after 10 days of feeding in the choice feeding trials. However, it took only 1-5 day of feeding of the same concentraction of bait prepared in wheat flour and sugar (98:2) to kill all *B. bengalensis* (Table 5). Ten days choice trials resulted in only 50% kill of *R. rattus* (Table 5).

Table 5. Efficacy of 0.0375% coumatetralyl bait against *Rattus rattus* and *Bandicota bengalensis*.

	No. of feeding days.	Poison ingested mg/kg	Mortality	Days to death Mean	(Range)
No-choice feeding					
Rattus rattus	1	35.27	1/10	6.0	(—)
	3	112.81	3/10	7.3	(7-8)
	5	138.79	5/10	9.4	(5-15)
	7	158.65	7/10	11.7	(7-18)
	10	176.47	10/10	11.6	(7-15)
Choice feeding					
	10	42.08	5/10	7.0	(5-11)
Bandicota bengalensis					
No-choiee feeding					
	1	50.53	10/10	7.3	(3–10)
	3	117.16	10/10	8.4	(4-13)
	5	88.30	10/10	5.3	(2-9)
Choice feeding	5	60.93	9/10	6.6	(2-9)

Warfarin (0.025%) in wheat flour and sugar (98:2) resulted in absolute kill of *R. rattus* only after 10 days of no-choice feeding (Table 6). Addition of phenylbutazone (0.002%) in the warfarin bait has been found to enhance the toxicity of the bait and it decreases the period of mortality. Ten days choice trials, however, revealed only 50% kill of *R. rattus* (Table 6).

Table 6. Efficacy of warfarin against the house rat

No. of feeding days	Conc. of poison poison used	Poison bait intake (g) 100 g body wt. raid	survived	Mortailty	Days to death Mean	(Range)
No-Chioce feeding						
5	0.025%	6.07±0.49	5.73±0.49	6/10	6.7	(5-10)
10	0.025%	4.67±0.37	-	10/10	9.0	(5-12)
8	0.050%	9.77±0.64	9.78±0.61	6/10	8.5	(7-10)
Choice feeding						
		Bait intake (g)/100 boby wt.				
		Poison (a)	bait plain bait (b)			
10	0.025%	2.57+0.23*	5.35+0.28	5/10	10.4	(6-16)

*significant difference between 'a' & 'b' (PL 0.01).

One day no choice feeding of zinc phosphide at 1.0, 1.50 and 2% concentrations resulted in complete kill within 24 hours (Table 7). Similarily single day no-choice feeding of RH-787 at 0.5, 1.0 and 2.0% concentrations resulted absolute kill of *R. rattus*. *Golunda ellioti*. *B. bengalensis* and *T. indica* within 24 hours (Table 7).

Table 7. Efficacy of Zinc phosphide against *Bandicota bengalensis*.

Dose (%)	Poison consumed mg/kg	% kill	Time taken to death (hr ± S.E.)
0.125	19.00 ± 3.48	50	—
0.25	34.37 ± 14.62	75	—
0.5	99 99 ± 8.69	100	6.59 ± 0.15
1.0	152.99 ± 5.88	100	5.58 ± 0.15
1.5	297.30 ± 35.64	100	5.32 ± 0.17
2.0	237.36 ± 18.33	100	2. 5 ± 0.13

Efficacy of Barium carbonate against *R. rattus*, *R. meltada* and *B. bengalensis* revealed that single day feeding of 12.5% barium carbonate bait could result in 5% mortality in all the three species of rodents. In case of *R. meltada* absolute mortality could be registered only after feeding the rate 20% bait in no-choice trials (Table 8). Evalution of Silmurin at 0.05 and 0.1% concentration in wheat

Table 8. Efficacy of barium carborate (Ratex) against different murid species.

Murid Species	Conc,	% mortality	Time taken to death (hrs.)
Rattus rattus	10%	50	12-24
	12.5%	50	12-24
Bandicota bengalensis	10%	50	12-24
	12.5%	50	12-24
Rattus meltada	5%	0	0
	7.5%	20	18-24
	10%	50	6-12
	12.5%	50	6-12
	20%	100	6-24

flour, indicated that Single day no-chice feeding (0.05%) resulsed in 50% kill of *R. rattus*, 85% kill of *Mus musculus* and 90% kill of *B. bengalensis*. However, no mortality was observed by increasing the silmurin dose from 0.05% to 0.1, absolute kill was obtained in one day feeding trials of *B. bengenlensis* (Table 9).

Table 9. Efficacy of silmurin against various murid species

Species	Conc. (%)	% mortality	Poison consumed mg/kg	Days to death Mean (Range)
Rattus rattus	0.5	69.23	3.91	2.11 (1-8)
	1.0	63.64	—	1.0
Bandicota bengalensis	0.5	90.0	2.73	1 0(—)
	0.1	100	—	1.0(—)
Mus musculus	0.05	85.71	8.33	1.0(—)

Studies with flocoumafen, another single dose anticoagulant revealed cent per cent mortality of *B. bengalensis*, *R. rattus*, *G. ellioti*, *T. indica* and *R. meltada* at 0.005% concentration in 1-2 days feeding. The rodenticide appeared more effective against *B. bengalensis* than *R. rattus*, as evidenced by cent percent kill of the former species at lower concentration (0.0025%) too, whereas only 60% of *R. rattus* died at this dosage in nochoice tests.

Results of evaluation of cholecalciferol (0.075%, a vitamin D_3 based compound) ready to use bait against four species of rodents viz, *R. rattus*, *Mus* sp, *T. indica* and *G. ellioti* showed poor acceptance of bait leading to 50-70% mortality in 2 days feeding time in choice tests. The mean days to death was 2.3-7.4 days for different species. Freshly prepared baits using locally available bait material were found superior to the ready to use commercial formations containing wax.

11. Field evaluation of rodenticides

Five rodenticides viz., RH-787, zinc phosphide, aluminium phosphide, brodifacoum, bromadiolone and flocoumafen were evaluated for their field efficacy individually or in combinations.

11.1 *Field evaluation of acute toxicants and fumigant in combinations :*

Two treatments with aluminimum phosphide reduced the rodent activity by 66 to 75% in groundnut, paddy and wheat fields. Two aluminium phosphide tablets (0.6 g each) were inserted deep inside each freshly excavated burrow with the help of an applicator. First treatment could reduce the burrow count by 50%, 59.38% and 57.81% in these crops respectively. Immediate second treatment further helped in reducing burrow count by 75%.

Two treatments with 2% RH-787 baits proved highly effective in producing 85 to 92.65% rodent mortality in groundnut, paddy and wheat fields. Immediate second treatment stepped up the mortality data from 59 to 78% to about 90% thereby indicating no bait shyness developed in rodents when RH 787 baits were reused.

Use of aluminium phosphide as a follow up action also proved effective particularly in paddy fields: 45.45% increase in mortality was recorded after fumigation.

Zinc phosphide at 2% concentration when tried in groundnut paddy and wheat crops, 57% to 73% mortality of rodents was recorded. Immediate second treatment with RH-787 further reduced the rodent activity and 89 to 92% success was achieved in these three crops.

First treatment with zinc phosphide (2%) followed by RH-787 (2%) also proved

effective in reducing rodent population by 75% to 84%.

III.2. *Rodent control in sugarcane crop* :

Efficacy of various rodenticides individually and in combinations have been tested in relation to ecological and behavioural parameters of rodents. These trials have been carried out in an area of about 30 hectares of Central State Farm, Ladhowal. The brodifacoum and bromadiolone at their 0.005% concentrations were prepared in bait mixture of wheat flour: maize: flour: groundnut oil : sugar (48:48:2:2) and zinc phoshide (2.5%) was prepared using wheat and millet grains. The following combinations of rodenticides were treated in sugarcane fields.

I.	Brodifacoum	—	Brodifacoum	—	Zinc phosphide
II.	Brodifacoum	—	Brodifacoum	—	Brodifacoum
III.	Zinc phosphide	—	Brodifacoum	—	
IV.	Zinc phosphide	—	Zinc phosphide	—	Brodifacoum
V.	Zinc phosphide	—	Zinc phosphide		
VI.	Bromadiolone	—	Bromadiolone		
VII.	Bromadiolone	—	Zinc phosphide		
VIII.	Zinc phosphide	—	Bromadiolone		

Marked differences in the control success in different fields as well as between treatments in the same field have been recorded. In field the control success of 67.2% and 69.3% (mean of both the census methods) was achieved but after second treatment of 0.005% brodifacoum, a many fold (338.990) increase of rodent population was observed. The period of this treatment coincides with the harvesting of adjoining paddy fields. Similarly in the second field 30.5% and 66.9% control of rodents was achieved with first and third treatments respectively but after the second treatment many times (212.1%) increase of rodent activity was observed. The increase of rodents activity in these fields was not due to the failure of the control but due to the failure of the control but to heavy reinfestation from adjoining harvested crop-lands. The treatments in field III were carried out in a relatively wet season, which resulted into poor control success. Poor control success in some other treatments can also be attributed to rainfall and meteorlogical factors. Zinc phosphide treatment separately in field VI and combined with brodifacoum in field No IV remitted in more than 80% control success.

The fields VI to VIII were treated with bromadiolone and zinc phosphide in three different combinations (Table 10). These treatments were made in relatively dry period after paddy harvesting when the chances of rodent reinfestation were minimized. In all these treatments 49.03 too 100% success of rodent was achieved.

The performance of poison was noticed to be effected by climatic factors as well as post control reinfestation as a result of breeding and immigration of rodents from nearby fields of wheat paddy rotation of flocoumafen (0.005%) resulted in 85.57%

Table 10 Rodent control in sugarcane fields using Brodifacoum and zinc phosphide combinations.

No. of field & treatment	Method of census	Success of first treatment	Success of second treatment	Success of third treatment
I				
Brodifacoum-Brodifacoum	Trap census Rodent 100 trap 24 hour	81 92%	Increase in* rodent population by 566.69%	58.45%
Zinc phosphide	Bait census g/Bs	52.54%	Increase* 111.61%	80.06
II				
Brodifacoum-Brodifacoum	Trap census	30.53%	Increase* 377 95%	72.11
Brodifacoum	Bait census	—	Increase* 46.31%	61.75
III				
Zinc phosphide	Trap census	0.0%	5.41%	—
Brodifacoum	Bait census	44.95%	34.58%	—
IV				
Zinc phosphide-	Trap census	73.69%	77.28%	71.15%
Zinc phosphide-Brodifacoum	Bait census	94.40%	93.34%	86.60%
V				
Zinc phosphide	Trap census	91.30%	86.74%	—
Zinc phosphide	Bait census	89.95%	100%	—
VI				
Bromadiolone-	Trap census Rodents	19.23%	100%	
Bromadiolone-	Bait census/g/BS/24 hr.	78.83%	100%	
VII				
Bromadiolone	Trap census	21.40%	39.18%	
Zinc phosphide	Bait census	100%	100%	
VIII				
Zinc phosphide	Trap census	57.77%	68.80%	
Bromadiolone	Bait census	100%	100%	

*Indicate increase of rodent population.

control success against in single treatment (67-75% success), wherein, Zn_3P_2 (2.4%) baiting yielded 51% and 61%. Control success with one and two baitings respectively in sugarcane fields, bait broadcasting and grid baiting at 100 bait stations/ha we more effective than baiting at periphery of fields.

11.3 : *Rodent Control in groundnut field :*

In groundnut fields the study indicated that 2 treatments of either brodifacoum or bromadiolone (0.005%) at 10 days interval between 80-120 days after planting were more eflective (72.37 and 67.25% success) than single treatment of these rodentic ides or zinc phosphide (42, 26, 40.88 and 58.07% respectively), Looking at

the value of the losses it was apparent that rodent damage of even 1% would justify the rodent control in groundnut.

Rodent control in wheat crop :

These wheat crop (varieties WL-1562 and WG-711) fields were selected randomly. In these fields at the start of trial the crop was at the tillering stage with 6-9" height. Burrow, bait and trap indices taken in the pre-treatment and post-treatment census. In each experiment at plot 30 to 40 traps and bait stations were placed in a grid manner at 15 meters distance. Poison baiting was carried out for 3 days with 10 g bait on each of the 40 bait points per hectare. Post treatment census was done after 15 days of poison treatment. The left over population was given another 3 days poison treatment with 0.005% broadifacoum bait and again post census was taken after 15 days.

First treatment resulted in a mean reduction of rodent population by about 60.4% (Table 13). The second treatment resulted in overall control success of 93.4%. Consumption of the poison bait during the first treatment was about 442 g/hectare which decreased to 180 g/hectare during the second treatment. It was also found that addition to brodifacoum in the bait had no effect on bait acceptance. The timing and stage of crop at which the natural food become available in abundance to the rodents had a marked effect on the control success with brodifacoum. Poison baiting in two different wheat fields during the first week of January and February when the crop was at the tillering stage, resulted in 88% and 73% reduction in

Table 13 : Result of poison baiting with brodifacoum against rodents in wheat crop fields.

Treatment	Census method	No. of traps/ bait stations per hec.	Pre-control census	Post control census	Reduction of rodents	Activity
First	Live burrows counts per hec.	—	26.0	10.3± 1.5	60.4	—
	Trapping rodents/100 traps/24 hours.	30	42.2± 11.6	14.45± 7.80	65.8	
	Bait census g/day/bait station	33	3.9± 0.3	1.42± 0.3	58.10	
Second	Live burrows counts per hac.	—	—	4.3± 2.3	83.5	
	Trapping/ rodent 100 trap 24 hours	30	—	0+0	100.0	
		33	—	.15± 0.06	95.5	

rodent activity. respectively, At the milky stage of the crop in late February, the control success was much low (46%). At maturing stage of the crop in march brodifacoum treatment resulted in 78.5% reduction of rodent population.

Double treatment of cereal bait brodifacoum (94.13% success) were reported to bc significantly superior to the two treatment of its wax bloek formulation (99.5% success) in wheat. However Zn_3P_2 treatment followed by cereal bait of brodifacoum (93% success) was at par with two treatments of brodifacoum. Single treatment of flocoumafen (0.005%) resulted in 67.4% control success which was at par with Zn_3P_2 treatment (65.8%). Effectiveness of single baiting with bradifacoum and Zn_3P_2 worked out. Total benefit acheived by these treatments amounted to Rs. 32863, 288.4 and 260.98, respectively.

The pulse baiting with brodifacoum and bromadiolone is successful in supressing rodent populations below economic threshold (Table 14). These trials gave almost 100% success. The trial with brodifacoum followed by brodifacoum also proved, to be satisfactory (81.20% success.) The zine phosphide trial gave only 46.96% reduction and its subsequent treatment after 1 month gap even was futile as only 35.33% reduction in rodent populations was recorded.

Table 14 : Efficacy of pulse baiting of rodents with brodifacoum and bromadiolone in wheat crop fields

Treatment	Method of census	Pre-control census	Post control census	Control success (%)
Bromadiolone	Burrow/hectare	13.33	0.67	94.97
	Bait consumption (g/bait station)	1.71±0.29	0	100
Brodifacoum	Burrows/hectare	10.67	0.83	92.2
	Bait consumption (g/bait station)	1.76±0.33	0	100

11.5 *Rodent control in paddy crop* :

Two poisons viz., brodifacoum (0.005%) and zinc phosphide (2.5%) were used for control of rodents. Brodifacoum treatment in a area of 4 hectares resulted in 47.63% (trap census) and 64.4 (bait caused) control success. Treatment with zinc phosphide bait at at different timings revealed variable results. First trial in humid environment resulted only in 30.4% (trap census) and 53.9 K (bait census) control success in an area of 4 hectares. However, in anotoer separate trial 2.5 hectares area, 69.57 (trap census) and 89.42% (bait census) control success was achieved.

12.0. Studies on Non-rodenticidal methods control

12.1. *Attractants/Repellents of plant origin* :

Twelve substances containing volatile are extracts of seeds of plants and hing were evaluated in bi-choice and multy choice trials for their attractant or repellency effects against rodents. Of these 0.1% lemon grass oil, 0.1% oil of mentha, 0.1% nil oil and 0.001% methyl enginol were found to attract *B. bengalensis*, while others, such as celery seed oil, spermint oil, basil oil, fennel oil, hing and citronella oil showed significant repellent effect.

12.2. *Cultural control methods* :

Field experiments revealed that rodents prefer non-weeded plots of wheat for burrowing and showed more activity and damage on these fields compared to weeded fields. Weeding of the crop fields at crop growth stage not only enhance crop productivity but also reduces the attraction of rodents and their damage in crops.

12.3. *Chemosterilants* :

A chomosterilant, alpha-chlorohydrin was studied in detail for its efficacy against the lesser bandicoot rat. The sterilant acts as toxicant at higher dosages. In no-choice and choice test, alpha-chlorohydrin. at a 0.5% conc in baits was found to be most effective against this rat. It was observed that the bait consumption decreased with increase in its concentration. Single day exposure of 0.5% alpha-chlorohydrin induces toxic as well as anti-fertility effect in the test rodents Studies on various reproductive parameters revealed that male *B. bengalensis* develop permanent sterility (as evident from the presence of spermata coels in their caput epididymis).

This chemical appeared quite species specific as it was less effective against *R. rattus*. The LD_{50} value for *B. bengalensis* was 81.56 mg/kg and at 100 mg/kg land it causes cent percent mortality. However at 75, 80 and 90 mg/kg land it causes permanent sterility in males.

Field trials with this sterilant at 0.5% conc in baits have been conducted in wheat, paddy in sugarcane. The success achieved was 48.3-81.9% in wheat, 49.1-[illegible]% paddy and 63.7-82.9% in sugarcane.

Burrows of *B. bengalensis* present either in waste land or on bound were treated with 0.005% brodifacoum bait. The poison bait was placed inside as well as out-outside the burrows. To study the response of rat towards the brodifacoum bait inside the the burrows, one polysac each containing 50 g bait was inserted 6" to 12" deep in 50 live burrows. Each polysac was tied with a wire a wire fixed to a rod, so as to moointer the response of the roddent by digging the burrow along the thread.

Brodifacoum bait in the ploysac tied with a thread to a fixed support were also placed out slde the 100 live burrow holes.

Placment of brodifacoum bait inside the burrow of *B. bengalensis* in waste land and on bunds elicited its response in 47 burrows out of 50 resulting to 56% reduction in live burrows count. The rodent showed a poor response when the polysacs containing the posion bait were placed outside the live burrows only 27 sacs out of 100 were seen either drugged inside the burrows or teared by the rat out side and only 20 burrows became dead.

13. 0. Rodent management in Poultry farm.

Studies on various aspects of rodents viz. species composition, food and feeding habits, mode and extent of damage (to poultry feed, chicks and eggs) were conducted in different poultry farms in and around Ludhiana; including those at Punjab Agricultural University Campus.

13. 1. Species composition :

Four species of rodents viz., in descending order of dominance *Rattus rattus, Mus musculus, Bandicota bengalensis* and *Tatera indica* have been recorded.

13.2. Food and feeding habits :

To study the food and feeding habits, stomach contents analysis was made by using displacement method. Results indicated occurrence of maize, rice—polish, groundnut cake, fish meal, flesh hair, plant matter (mostly *Philaris minor; Triticum aestivum*, cucumber), insect parts (of family Formacidae, *Monomorium indicum*, chrotogonus sp.,) stone pieces and feathers). Maiza constituted the bulk of the food in all the species varying from 59.7% to 69.15%. Rice polish and groundnut cake were found to be in the form of green fibre like matters and insect parts appear to be accidentaly. The preferences for other food materials varied from species to species.

13.3 Percent loss to eggs :

It was observed that mean precent damage was mixinum in January and decreased thereafter. On an overage, of the total daily produce, 0.29% eggs were damaged by rodents per day.

13.4 Percent loss to gunny bags :

Mean percent damage was calculated to be 10.20 ± 2.54. It was further calcutated that an average poultry owner losses rupees 20.60 per month due to manage of gunny bags by rodents.

13 5 Percent chicks killed by rodents :

The observations indicate that rodent attack and killed young chicks upto the age of 30 days. Only the house rat, *Rattus rattus* was observed attacking young

chicks. The percent loss to chicks by rodents was worked out to be 94.60 rupees per thousand chicks.

Behaviour and control of rodents in poultry farms :

For the effective treatment of house rat, *Rattus rattus* and house mouse, *Mus musculus* in poultry houses, specially design bait boxes were tested for food preference of rodents. They have been found to take significantly more bait from closed containers than from the open trays. Single 3 days treatment each with 0.005% brodifacoum and bromadiolone baits in closed containers resulted in 97% and 80.8% reduction in rodent activity in the separate poultry houses, respectively. But one similar treatment brodifacoum resulted only in 56.2% reduction in feeding activity of rodents in another poultry house where percent population was much higher and 88.8% reduction in rodent activity was recorded. A rodent trap and a poultry bait station designed by the Project Scientists of this centre have been found effective for 70-100% control success in poultry farms. A mixture of wheat flour, groundnut oil and sugar (96:2:2) was found to be most acceptable baiting medium for rodents. Poultry feed was about 5 times less preferred than wheat flour by *R. rattus* inhabiting the poultry farms.

Social Engineering Activity on Rodent Control

Opinion Survey

Impact of education and training of farmers and socio-religious factors on the acceptance and effectiveness of rodent control technology has been studied under this Project in four adopted areas (about 250 hectares of crop fields at each site) of different villages of punjab including residential premises. New villages were later adopted after 4-5 years of continous study in their villages. The opinion survey of rural families regarding rodent control pre-operational and post-operational rodent population and crop production assessments were carried out in all the areas.

Survey in rodent control opinion and interest of rural community :

At the begining of this programme 22-27 families were interviewed Maintenance area, Neglected area I, Neglected area-II, Survey area, to know their opinion, socio-religious beliefs, interest and experiences regarding rodent control operations. After three years of continuous operations in the adopted area this type of survey was repeated (with a sample of 50 families from each area) to compare changes in the responses of rural community of various adopted villages towards rodent control operations.

Interest in Rodent Control :

All the rural families were found taking interest in the control of house rodents but their interest regarding control of field rodents varied from 55.55% to

77 27%. All the farmers interested in rodent control were doing something to reduce the rodent population in their respective fields. After three years of continuous education of farmers about damage and control of field rodents an increase of interest was observed in all the areas maximum being in 'Maintenance area'. An incrase of 15.2% in interest of farmers of "survey arca' was also observed which might be due to the fact that farmers learn about rodent damage in formaly during our survey programmes.

iii. *Bclief in rodent damage* :

All the farmers interested in rodent control believe that rodent cause considerable damage and its population must be reduced. Those farmers who do not feel that rodent cause extensive damage to crops, did not show interest in rodent control in the fields. These observations clearly indicate that farmers interest in rodent control is linked with realisation of damage by them. In the IInd survey an increase (15.21% to 21.6%) in interest towards rodent control in fields apparent.

iv. *Use of Rodenticides and Traps* :

Use of zinc phosphide was found very frequent not only in fields (55,55% to 77.27%) but also in houses (8.7 to 32%). Though zinc phosphide is not recommended in houses because of its high toxicity to mean and domestic animals and absence of any specific antidote, But farmers believe that this is only effective rodenticide at present. The use of zinc phosphide increased for rodent control in fields in all the areas after three years of persuation by 15.21% to 21.65% except in Neglected area-II (decreased by 20.27%) where farmers complained its inavailability from the market. The use of zincphosphide in the houses decreased to some extent where warfarin was supplied by us alongwith discouragement for the use of zincphosphide in the houses. At the same time a sharp increase of its use in for control of house rats was seen in survey area.

Farmers were either not aware of anticoagulant rodenticides or they know it as an ineffective chemical, therefore use of such rodenticides was negligibie. After a tough perusal the farmers adopted warfarin in houses where it was supplied by us. However, they were not seem to be sincere in placing and replenishing the baits in the recommended way. They continued to use zinc phosphide and traps alongwith of warfarin in houses.

v. *Control Operation* :

The initial survey revealed that the method followed for the prepration of zinc phosphide bait was not proper observations 6) Most of the farmers were using zinc phosphide in moist wheat flour or in raw fruits. The appropriate method was follwed as low as by 13.33% to 35.22% farmers. But a great success in the proper use of rodenticides was achieved in Maintenance area as over the previous years

increase (183-37%) of farmers began to use of zinc phosphide with the recommended method.

The pre baiting practice before use of zinc phosphide was not followed earlier. After education of farmers it was adopted by 100%. farmers in maintenance area and 46.34% in Neglected area-I while in other two areas it remained as in previous years.

vii. *Opinion about Control operations* :

A very low degree of satisfaction towards control operation was observed in the first survey. After three years in second survey the number of farmers satisfied with their control attempts increased from 31.25% to 80.85%. The highest level of the same was observed in the maintence area. In houses results were not as good as those of fields. This was mainly because use of first generation anticoagulants did not prove very successful.

viii. *Opinion about Failure of Control Operations* :

The farmers believed that the main reasons for the failure of zincphosphide in fields was due to bait aversion and ineffectiveness of poison bait. The poison aversion might be the result of individual control operations with sublethal poison concentrations in moist baits. The ineffectivenses was probably because of its use in moist bait at low concentrations and availability of adultrated zinc phoshide taken from the market were found completely inert on the basis of oral feeding laboratory trials on *Rattus rattus*. After three years of operations with the demonstrations of the effectiveness of the zinc phosphide baits the opinion of the farmers changed considerable. The belief of farmers about poison changed during second survey and it was mainly due to the adoption of recommended methods for the preparation of zinc phosphide baits. The complaints of in effectiveness of the zinc phosphide reduced to zero in maintenance area and neglected area-I where it was supplied by US after a thorough testing in the laboratory but at the same time in Neglected area II it increased by 61.55%. However a low decrease (6.26%) in this regard was observed in survey area. In houses bait shyness towards zinc phosphide decreased by 64.52% 18:18% and 21.00 in 1st. IInd and IVth areas. However, in neglected area I an increase in bait shyness was observed. The result of 1st area might be due to wrong method adopted as it was not recommended in houses. In maintenance and neglected area I where warfarin supplied by US, was referred as ineffective rodenticide by most of the farmers (36% to 66%). This is because of their impatient behaviour in getting results of their control treatments. Actually they could not use warfarin properly. It might be also a fact that rodents do not eat the bait regularly for 15 days. Trap shyness found to be reducing after education and training of farmers as they adopted the proper method of use :n houses.

viii. *Food grain storage* :

Economically sound farmers who store grains for consumption only 21.7% were found using proper storage bins. While others were using jute bags for storage of grains. An increase in use of proper storage bins were observed in all adopted areas maximum (197.30%) being in neglected are I but the level (30%) of use of the same remained higher in the maintenance area.

14.2 *Results* :

The results of rodent control success varied during different years in rabi and kharif crops as well as in different selected areas. The control operation were found most successful in maintenance area where control success was recorded from 73.93% in rabi crops in the year 1978-79; 48.2% in kharif crops in 1979. In the subsequent years, trap index was relatively low in maintencnce area and further treatments both in rabi and kharif crops gave sufficient good results. In 'Neglected area -I' the success of control treatment varied from 20.3% to 53.3% being maximum in Kharif crop 1980-81. The possible reasons for low success may be that farmers did not follow the appropriate rodent control technology in this area. In 'Neglected area-II first control treatment in 1979 provided completely ineffective. Moreover an increase of 37.78% in the trap index was observed after post control census in this area. All the treatments in this area resulted in low reduction of rodent population. Low success of anti-rodent campaign may be due to the reason that farmers did the control at different times covering only cropped area and did not follow the strategy explained to them. However, in the subsequent years, the population of rodents decreased in survey area the rodent population was increasing year by year and reached as high as 32.67% rodents per hundred trap per day 1979-80. Thereafter, the rodent population decreased in this area.

It was found that the effect of rodent control on production of various crops was not very clear as many other factors like seasons, soil conditions, irrigation, fertilizers, insecticides, variety of seed and agronomic practices have the impact on production.

In houses rodents were killed twice a year in the month of march and september. The poison treatment were carried out with 0.26% warfarin for 15 days. In these operations, farmers refused to cooperate after 4-5 days from the begining of control operation. This hampered the rodent control operation and hence the desired results could not be obtained. But the results are improving year by year. In 1982 in maintenance areas farmers fully cooperated and results were quite encouraging.

Social engineering activity was continued in subsequent years in 8 villages of Ludhiana viz. Katana, Bermalipur, Jaspalan, Beeja, Majara,, Medhpur, Ajnaud and Bilga during rabi and kharif season. The villages were marked as maintenance area

(M), neglected area-I (N_1), neglected area-II N_2 and survey area (R) respectively. The common species damaging crops in this area were *Tatera indica*, *Rattus meltada*, *M. musculus*, *M. booduga*, *M. platythrix*, *Bandicota bengalensis* and *Golunda ellioti*. Low incidence of rodent damage activity was observed in maintenance (M) area as compared to N_1, N_2 and survey area.

In 1987 in the kharif season (paddy) there was 90% reduction in damage in maintenance area and 34-89% reduction in neglected area as compared to survey area. Similarly, there was 72% reduction in rodent activity in wheat in the main maintenance area whereas there was 2.4% increase in rodent activity in neglected area.

Regular control operation can easily regulate the rodent population numbers to a level which may not be detrimental to the crop production, processing and damage.

ICAR Research Complex For NEH Region, Shillong

This Co-operating centre of AICRP started during 1983 with the following specific mandates :

1. Survey, collection and identification of rodent pests in different habitats of NEH Region.
2. Evaluation of existing and newer rodenticides under laboratory and field conditions.
3. Management of rodents in poultry farms.
4. Reproductive biology of major rodent pests.
5. Assessment of losses caused by rodent pests in rice, maize and pineapple.
6. Rodent management in waste lands/fallow lands, *jhoom* fields and its impact on rodent infestation patterns.
7. Rodent management techniques especially for jhoom and terrace cultivation areas, bamboo forests and residential premises.
8. Social engineering activity on rodent control.

The research finding of the centre are summarised below :

1. Species composition

The North Eastern Hill Region is reported to be quite rich in rodent fauna. As many as 7-8 species which are of major economic importance were found to inhabit these areas. The surveys at Shillong (1500 amsl), Cherapunji (750 amsl), (1150 amsl), Nongpoh (660 amsl) and Tura (675 amsl) in Meghalaya revealed occurrence of *Rattus nitidus*, *R. rattus*, *R. norvegicus*, *B. bengalensis* and *Mus musculus*. In the Kolasib region of Mizoram the major rodent species were *R. norvegicus*, *R. nitidus*, *R. bowersi*, *R. r. khyensis* and *M. musculus*. In the bamboo flowering areas of Bomadilla Changalang of Arunachal Pradesh, *Rattus* group dominated the area whereas in Manipur, *R. bengalensis* and *R. Rattus* were almost equally distributed as the most predominant of *Rattus* group viz., *R. rattus*, *R. norvegicus*, *R. nitidus*. *R. bowesri*, *R. r. khyensis* constituting 50% of total collections followed by *Mus musculus* (30%) and *B. bengalensis* (8.26%) in Meghalaya and Mizoram.

Table 1 : Rodent collection at different elevations in NEH Region

State/UT	Place of collection	Altiude	Species
Meghalaya	Shillong	1500 M	*M. musculus, R. rattus. R. norvegicus, B. bengalensis*
	Barapani	800 M	*M. musculus, M cervicolor, M. booduga, R. nitidus. B. bengalensis, R. rattus*
	Tura	400 M	*M. Musculus. R. nitidus, R. rattus, R. r. khyensis, B. bengalensis*
Mizoram	Alzwal	1500 M	*R. rattus*
	Kolasib	800 M	*R rattus. M. musculus, R. nitidus*
Arunachal Pradesh	Bas	800 M	*M musculus. R. nitidus, R. rattus, B. bengalensis.*

II. Infestation patterns

Survey of rodent pests infestation at Tadong, Sikkim during 1987 revealed highest burrow density per hectare in pineapple fields (9.00) followed by lowland (6.67) and upland cultivated areas (4.25). In Meghalaya general infestation was higher during 1987 than that in 1986, Uncultivated areas exhibted comparatively lesser infestation than that of cultivated area. Uplands showed least active burrow density

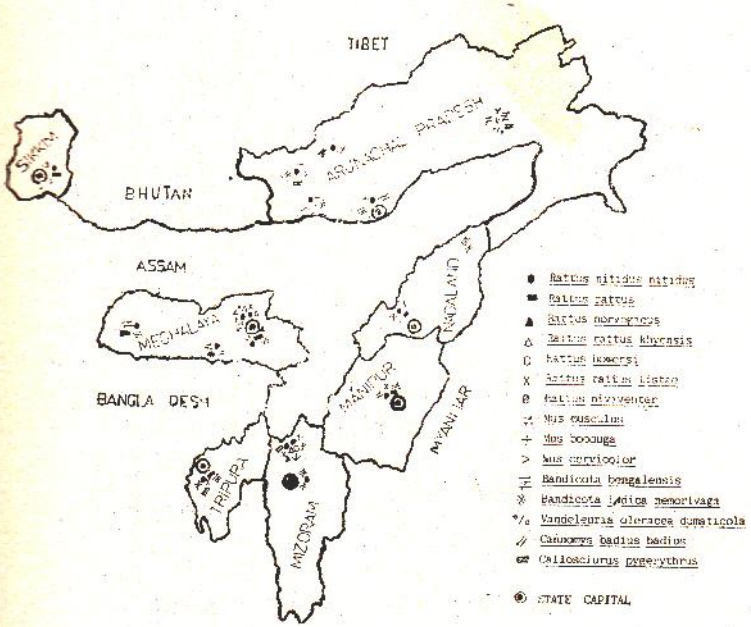


Fig. 1. Distribution of Rodent Species in Neh Region.

(6.7/ha) than the wetland rice, terraced crops and citrus orchards in 1987 (with 23.4, 24.0 and 50.4 active burrows/ha). In Mizoram, surveyat Kolasib revealed that terraced land under paddy has maximum burrows (40/ha) followed by vegetable cultivated area in 1986. In Agartala (Tripura) poultry farms with an area of 0.7 ha showed 67 active burrows. In the fields the rodent burrow density ranged between 5.83-22.00 per ha.

Monthly observation for 4 years at Barapani Research Farm (Shillong) revealed highest burrow density per hectare during August, September and October months, and minimum during December, January and February There is a small increase in the burrow density per hectare in this research farm ranged between 0.1 in June (1985) and 1.70 in August (1990). During 1991, the Kolasib (Mizoram) farm recorded 5 active burrows/ha whereas at Barapani Farm, 37.5% active burrows were noticed during March-September. Rodent activity was at its peak in August (1.77 burrows/ha) and lowest during March (0.51 burrows/ha). The activity of rodents was more pronounced in upland rice cultivated areas followed by pineapple fields.

3. Losses due to rodents

Rice, maize and pineapple are the most important crops of NEH Region where the rodents cause extensive losses. During 1985-86 the rice crop suffered 8.38 to

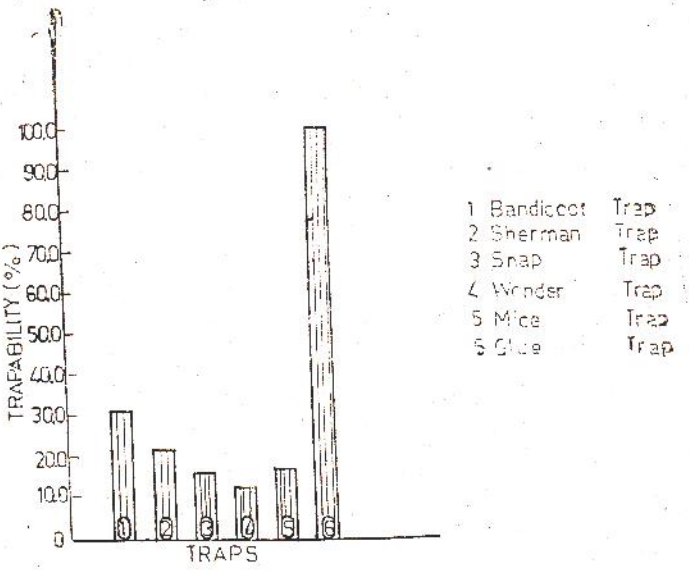


Fig. 2. Trapability of Different Traps.

at the tillering stage and the crop had to be harvested earlier to avoid further damage. In the preceeding years too the losses ranged between 1.67-22.61 percent. In case of maize the losses ranged between 11.5 and 12.2 precent at the milking stage. Highest damage of 34.14% was recorded during 1987. Similarly, pineapple was found to be most vulnerable to rodent attack during maturity stage of fruits. In various years under study the fruit damage was 4.94-12.75% at the Barapani Research Farm (Shillong). In Kolasib, groundnut crop was observed to suffer to the tune of 4.19% due to rodents. The maize crop at Barapani was damaged to about 14.38 and 17.8% at developing and maturity stage, respectively in 1991.

4. Breeding biology

Attempts were made to study the breeding biology of *R. norvegicus* (wild and albino), *B. bengalensis*, *R. nitidus* and *Mus musculus* in laboratory under captivity. The experiment could not proceed beyond the litter size due to cannibilistic behaviour of these rodents in captivity. The cannibilistic behaviour varied between 44.4-100% and 33.3-100% in *R. norvegicus* (wild and albino both) and *B. bengalensis*, respectively, whereas it was cent percent for *M. musculus* and *R. nitidus*. The litter size under captivity ranged between 4.0-6.5 for wild *R. norvegicus* and 2.5-7.0 for albino in various years under investigation. Similarly, the litter size for *B. bengalensis* was between 4.0-7.0 per female. Sex ratio (Male : Female) was also worked out in different seasons which ranged between 1:0.94 and 1:0.97 for different rodent species.

5. Parasites of rodents

The ecto and endo-parasites were recorded which included *Hydetigera teaniformis*, *Cysticercus facionaris* and *Hymenolapsis dimnata*. Total of 34.16 and 6.7 percent rodents collected during 1986 and 1987, respectively. Ticks, mites and fleas accounted for 45.67, 17.5 and 33.00% during 1986 and 46.29, 17.1 and 19.95% during 1987, respectively as ectoparasites were infested with endoparasites.

6. Studies on bait preferences

Out of 10 feeds (cereals, oilseeds and pulses) tested, *B. bengalensis* showed maximum preference for wheat flour (kneaded balls) followed by rice, maize, gram and lupin. When some additives like, oil and sugar/salt was tested on these five preferred baits, groundnut oil (2%) and sugar was preferred over mustard oil and salt. In another long term feeding trial with rice, paddy and ragi against *B. bengalensis*, *R. nitidus* and *Mus musculus*, rice was preferred by all the species. However, when maize and gram were also included in the trial, all the three test rodent species showed more preference for maize over gram and rice. Bamboo seeds of two species viz., *Dendrocalamus striatus* and *Bambusa arundiraceae* and paddy were tried for preference studies with *R. norvegicus*. It was seen that the seeds of latter species were preferred over the former one. Feeding on *B. arundiraceae* for 60 days resulted in weight gain

by males to the tune of 4.22% but females lost the weight by 4.97% whereas feeding on *D. striatus* resulted in loss in body weight by 15.85 and 14.97% for males and females, respectively.

7. Rodent behaviour

7.1 *Towards different traps :*

Various types of traps viz., large sherman (Bandicota type), sherman and snap traps were evaluated for their effectiveness. Out of 435 rodents collected, the large sherman showed 58.33% trapping followed by Sherman (51.67%) and snap trap (34.2%) in 1986. Similar trends regarding the efficacy traps was recorded in preceeding years under study. Both these types of sherman traps (Bandicota and normal) were found to have enhanced trappability to the tune of 46.67 and 43.33%, respectively when they were plastered with black paint.

7.2 *Burrowing pattern* :

This behaviour was studied in case of *B. bengalensis* at Marulai rabbit farm. Burrows measured 7.87 cm (5.8-11.5) in diameter and 25.42 cm (15.3-31.4 cm) in circumference. On an average 4.67% (2.19-7.33) of soil was excavated overnight per burrow.

8. Evaluation of rodenticides

Rodenticidal evaluation programmes included poisons like zinc phosphide, barium carbonate, aluminium phosphide, bromadiolone, brodifacoum and rodafarin. Most significant findings were in the field of preparation of new baiting medium for zinc phosphide treatment. Wax pellets and membrane coated pellets of zinc phosphide were found quite effective in containing rodent menace.

Wax coating was done with zinc phosphide mixed with wheat flour and oil in the ratio of 2 : 95 : 3. The pellets were prepared and it was seen that 2 g pellet size was most preferred by the rodents. *B. bengalensis* responded to this formulation and the deaths were initiated within 3 hours leading to cent percent mortality in 12 hours with actual consumption of 56.83-75.66 mg/100 g body weight. Comparative toxicity of 5 rodenticides against *R. norvegicus* in the laboratory revealed that zinc phosphide (2%) produced 100% mortality in 24 hours, whereas bromadiolone (0.005%), brodifacoum (0.005%), rodafarin (0.025%) and barium carbonate (10.0 %) could result in 50, 60, 70 and 70% mortality in 7-24 days. Of the three methods of zinc phosphide baiting i.e. plain, wax coated and membrane coated tried against *B. bengalensis* in laboratory, the membrane coated formulation resulted in 100% mortality with highest acceptance. On the other hand the loose bait and wax coated baits showed 60 and 20% response, respectively. The acceptance of membrane (mesenteron of goats) coated flour balls with 2% zinc phosphide was observed to be higher

than the uncoated flour balls (40.40.7%), wax coated flour balls (33.2%) and bread pieces (59.5%). Membrane encapsulation was reported to have increased keeping quality (Table 2).

Table 2 : Comparison of various zinc phosphide baiting techniques

Study area	uncoated flour balls eaten (%)	waxcoated flour balls eaten (%)	Gur coated flour balls eaten (%)	Bread pieces (1"x1") eaten (%)	Membrane coated flour balls eaten (%)
I	40.0	39.0	26.2	33.4	70.0
II	38.9	42.9	28 7	45.8	77.6
III	41.8	46.2	38.4	72.0	61.1
Total (Mean)	40.7	43.7	38.2	56.5	67.0

Rodenticidal trials in laboratory were conducted on *Bandicota bengalensis* with bromadiolone, flocoumafen and cholecalciferol. Single day exposure of 0.005% wax blocks of bromadiolone yielded cent percent mortality of bandicoots. The days to death was between 3-13 days (mean=6.89 days). Two and three days exposure of this poison resulted in 96 and 100% kill. However in choice tests, the mortality was reduced to 86.6 and 93.3% in 2 to 3 days exposure respectively. The acceptance of poison bait was poor in presence of an alternate bait. Similarly flocoumafen wax blocks yielded 95% kill of test bandicoots in one and two days feeding in no-choice. The death period was 3-15 days. In the choice test, the plain bait was significantly more preferred over wax blocks of the poison in 2 and 3 days feeding trials. The mortality was 90% (2 days exposure) and 95% (3 days exposure).

Cholecalciferol, a vitamin D_3 based rodenticide proved equally effective in control of *B. bengalensis*. In no choice tests for 1, 2 and 3 days exposure, the death rate was 70,90 and 100%, respectively and the respective days to death ranged from 3-14, 4-15, and 3-8 days. In choice test for 3 days exposure, the mortality of the test bandicoots was reduced (70%).

Zinc phosphide, an acute rodenticide was also evaluated against this bandicoot in laboratory at different concentrations viz., 1.0, 1.5 and 2.0%. The mortality under nochoice was 90-95% but the poison baits having 1.0 and 1.5% conc. were more preferred. In choice test, 2.0% zinc phosphide resulted in 80% mortality of bandicoot rats.

Extensive field studies with different rodenticides indicated that wax cakes of bromadiolone and brodifacoum (0.005%) were most effective anticoagulant poisons. Similarly, zinc phosphoide coated with membrane was found superior over other

formulations of zinc phosphide and bromadiolone in the fields having mixed populations of rodents. Aluminium phosphide tablets were also quite effective @ two tablets per burrow with a control success of above 90%. Loose baits have comparatively lesser potential in NEH Region because of being a high rainfall zone. In the residential premises wax cakes of bromadiolone and brodifacoum resulted in over 70% control success followed by zinc phosphide membrane coated balls (42% control success). Some of the specific field trials of rodenticides and detailed below :

(i) Bromadiolone wax blocks in godowns and Laboratories : The wax blocks of bromadiolone (0.005%) were found very effective in godowns and laboratories at Barapani Farm. It was consumed to the tune of 78.66% (range 72.72-90.00%).

(ii) Zinc phosphide in godowns : Two percent pellets of zinc phosphide were found effective in controlling rats in godowns at Barapani Farm. The poison was consumed to the tune of 45.78% (range 15.00-60.00%), and 23 dead rats were collected.

(iii) Bromadiolone wax blocks in urban areas : Bromadiolone wax blocks (0.005%) were found very effective in controlling urban rats. The consumption of cake was found to the extent 85.36% and a total of 298 dead rats were collected.

(iv) Zinc phosphide and aluminimum phosphide tablets : 234 active burrows treated with 2% zinc phosphide pellets resulted in the reduction of active burrows after one week. The remaining active burrows treated with aluminium phosphide at the rate of two tablets per burrow reduced the active burrows upto 98.85%.

(v) Zinc phosphide at Kolasib (Mizoram) : 2% poison bait of zinc phosphide in boiled rice was used in residential premises, godowns and fields for the control of rodents. The rats consumed more rodenticides in residential areas than in godowns or fields.

9. Social engineering activity on rodent control

This activity was restricted to large scale rodent control operations in residential premises, godowns, poultry farms and crop fields using zinc phosphide, aluminium phosphide and bromadiolone wax cakes. During 1990-91 a programme of public education and awareness about various methodology of rodent management was under taken and residential premises were selected for bromadiolone baiting. Monitoring of rodenticidal consumption of 102 rats were reported to be killed. Residents reported that the losses due to rodents have been substantially reduced. During 1991, 100 farmers of these adopted villages (viz., Mawtneng, Mawdar and Umtung) were approached for rodent control in the fields and houses. Almost all the farmers showed their reluctance in use of rodent poison, as it would affect their cats, dogs, pigs and poultry. Inspite of motivation to use rodenticides, the farmers preferred the use of domestic cats for rodent control, over rodenticides.

III. Rodent problem in Bamboo flowering areas

A survey of rodents was conducted in East Kameng district of Arunachal Pradesh, where bamboo flowering was observed in 1989-90. The flowering started in October-November 1989 and continued upto April 1990. According to the villagers residing near by, the rodent population increased during bamboo flowering. However, only 19 rodents could be collected from the area, representing the normal population of rodents of that area.

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

All India Coordinated Research Project at Jabalpur started on 3rd December, 1983 and now has been extended in VIII Plan. Most of the project work covered the applied aspects of rodents. However, the efforts were made untirely in completing some of the studies on different aspects of rodents. The research work done from Jan. '83 to March, '93, at this centre is reported here under.

1. Survey of Rodents

Regular surveys conducted in different agro-climatic zones, showed the occurrence of 10 rodent species. They were *Millardia meltada*, *Bandicota bengalensis*, *Rattus rattus rufescens*, *Tatera indica*, *Mus booduga*, *Mus musculus*, *M. m. urbanus*, *Rattus norvegicus*, *Mus saxicola* and *Funambulus pennanti*. Of these species, *M. meltada* and *B. bengalensis* were found to be ubiquitous. In residential premises mainly, *Rattus rattus rufescens*, *Mus musculus* and *Mus musculus urbanus* were found. In addition to these *B. bengalensis* was also trapped rarely in the houses.

On the fields, however, *M. meltada* and *B. bengalensis* were found to be major species. Monitoring of rodents also indicated activity of *M. meltada* and *B. bengalensis* throughout the year. The soft furred field rat, *M. meltada* was dominant during *kharif*, while *B. bengalensis* stood second. An upsurge of *M. meltada* was noted during *rabi* season. The proportion of distribution of *M. meltada* and *B. bengalensis* in soybean and gram crop was observed to be 65 and 35% at the peak activity of these species.

In different crops like, soybean, paddy, gram, wheat, sugarcane, vegetables (sweet potato) surveys were conducted for rodent association. Based on trap indices and burrow characteristics, their status in different crops is given in the Table 1. It is inferred that soft furred field rat was major rodent in pulse and oilseed crops, while bandicoot in cereal and sugarcane crops.

Table 1. Status of important rodents in different crops fields

Rodent species	Status	Crop
Millardia meltada	Major	Soybean, gram, groundnut, paddy, and wheat
Bandicota bengalensis	Major	Groundnut and sugarcane, wheat
Mus boodgua	Minor	Soybean and paddy

Rice, wheat, soybean, gram, and sugarcane crops were frequently surveyed for rodent infestation patterns. The results are summarised in Table 2.

Table 2. Infestation patterns of rodent pests in different crops

Crops	Rodent species
Soybean	*M. meltada, B. bengalensis, M. booduga*
Paddy	*M meltada, B. bengalensis, M booduga, M. musculus, F. pennanti*
Wheat	*M. meltada B bengalensis, M. booduga, M. musculus. T. indica*
Sugarcane	*B. bengalensis, R. r rufescens*
Gram	*M meltada, B bengalensis*
Groundnut	*M meltada, B. bengalensis, F pennanti*

It is depicted from the Table 2 that no single species is associated in a crop but complex of rodents are involved in various crops. It was further revealed that atleast 2 to 3 species of rodents are prevalent in each crop ecosystem.

Rodent pest complex in poultry :

The studies conducted on the composition of rodents in poultry, revealed the presence of *Rattus rattus rufescens, Bandicota bengalensis, Millardia meltada* and *Mus musculus urbanus*. Of these *R. r. rufescens* was found dominant. *M. meltada* was found in low proportion. The presence of *B. bengalensis* was found more, where the poultry farms were situated near fields but in less number to *R. rattus*.

2. Assessment of Rodent Damage in Crops

The assessment of damage due to rodents was done regularly in different crops (Table 3). The extent of losses varied from location to location, season to season, year to year, soil types, cropping pattern and situation of the field (near or away from residential premises, canals & threshing floors) and fields with and without weeds. The crop stand and plant density were also the governing factors in the build up of the rodent population. The lossess also varied from stage to stage of the crop.

Table 3. Extent of losses, caused due to rodents in different crops

Crop	Losses in yield (kg/ha)	Damaged plants (%)
Soybean	3.04 to 70	—
Rice	2.00 to 90	—
Wheat	1.00 to 200	—
Gram	0.20 to 33	—
Sugarcane	46.00 to 449	—
Groundnut	—	0.00 to 17.22
Opium	—	0.00 to 1.5

It is seen from the Table 3 that the yield losses varied to a greater degree in different crops. The losses were found to be highest in sugarcane crop, followed by wheat, rice, soybean, opium, gram and groudnut. The results further revealed that in case of lodged sugarcane fields burrow density was more as compared to

unlodged fields. The rodent damage in crops near villages was comparatively higher than these fields located away from the villages (Table 4).

Table 4. Assessment of rodent damage in soybean and rice fields situated near and away from villages

Field	Mean damaged pods/m² (No.) Soybean	Mean cut tillers/m² (No.) Rice
Near the village	4.86	2.16
Away from the village	1.47	1.47
't' (p = 0.05)	Significant	—

3. Distribution of rodent damage in different crops

3.1 *Soybean* :

In *Kharif* season, the damage of rodents start from seed germination stage and continue up to prematurity stage. The damage remain low at seedling stage to flowering stage. The damaging activity was more intense at seed formation stage. They cause more damage at green pod stage. The burrows are confined on bunds but as condition favours, the rodents start making burrows in crop fields. The damage is distributed in the fields from periphery to centre particularly at pod stage.

3.2 *Wheat* :

In wheat crop, the damage is observed from tillering to prematurity stages of the crop. The study conducted on the distribution of damage at the prematurity stage revealed that number of cut tillers were found significantly more in central portion of fields as compared to periphery and middle area. The mean number of cut tillers in periphery, middle and central part of fields were recorded to be 0.18, 1.75 and 6.40/m²

3.3 *Gram* :

The damage to gram crop is witnessed in the whole field from periphery to central part at pod stage of the crop. The damage is visually conspicous at podding stage of the crop.

4. Nature of Rodent Damage

4.1 *Soybean* :

The rats have been observed to cause damage apparently at podding stage of soybean crop. They have also been observed to cut the plants at seedling to vegetative growth stage of the crop. They cut the branches rarely in between vegetative to flowering stage. The damage is quite visible at the podding stage of the crop. The peak damage is seen at the time of seed formation in pods. The pod filling stage is the vulnerable stage for rodent attack.

The feeding behaviour of rats on immature soybean seeds is typical and can be differentiated from any other pest of soybean. Firstly, the rats nibble at the green pods and these ultimately fall on the ground. Then, they gnaw the fallen pods after picking them and eat the seeds through edges. Sometimes, they split the pod skin above the seed and take out the seed. At the damaging site, pericarp of seed are seen lying. The gnawed pods can be easily distinguished from the healthy green pods due to presence of gnawed edges. Similar damaging behaviour was also observed in gram pods. In gram the pod skin is not removed by the rats.

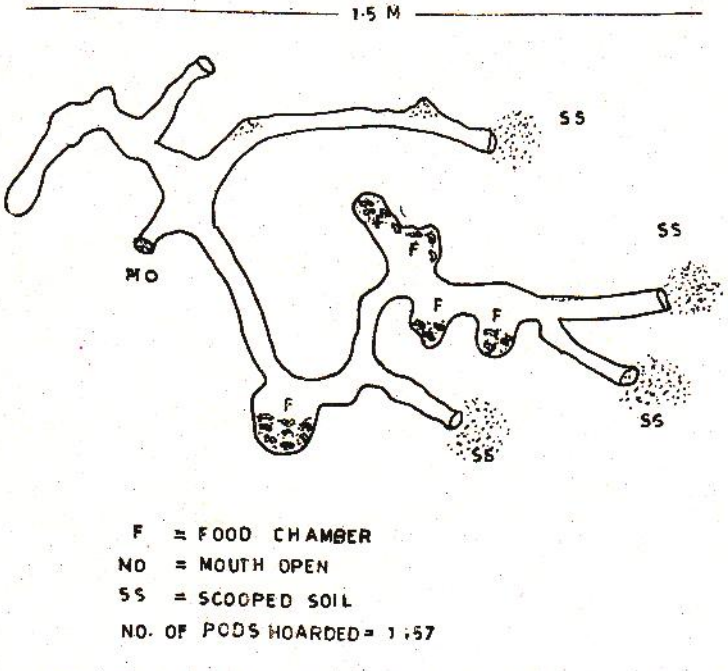
Feeding capacity :

In a laboratory test single animal of *M. meltada* was found to damage from 16 to 30 soybean pods in 24 hrs with mean of 18.7 pods. In case of gram it destroyed from 22 to 50 pods in 24 hrs with mean of 40.50 pods.

The rats also hoard the green to prematured pods in their burrows. The pod hoarding tendency was found more common in bandicoot as compared to soft haired rat. *B. bengalensis* was found to hoard maximum of 4132 soybean pods in a burrow (Fig. 1).

4.2 *Rice* :

The study on damage at prematurity stage of rice crop. The burrows of the rats were located on bunds as well as in fields with their well defined path ways



Flg. 1. Burrow structure of *B. bengalensis* in Kharif Soybean after Harvest in medium black soil with food chambers.

during pre-mature stage of rice. The above studies showed that damage started at the vicinity of the burrow opening and increased upto 3 m and covered upto 8 m distance. However, maximum tillers were cut at 7 m distance. The damage to tillers decreased after a distance of 8 m.

4.3 *Rabi crops (wheat and gram)* :

The present study was undertaken from December to April in *rabi* season (1983-84) by trapping animals at fortnightly interval (Fig. 2) in wheat and gram crops. The major rodent species in rabi crops were *M. meltada* and *B. bengalensis*. Results indicated that both the species were trapped throughout the season. In case of metad the population was found zero upto 2nd fortnight of December i.e. in vegetative stage of crop. The population ranged from 0 to 11 rats/75 traps. These pests was found more active during podding/earhead stage of gram and wheat crop and was prevalent upto maturity stage. The distinct rise in the population was observed during first fortnight of January and second fornight of February-March 1984. The population level declined with the harvest of the crop. Similar trend was also observed with bandicoot but its population was low as compared to *M. meltada*. It ranged from 0 to 7 rats/75 traps. Highest population was recorded

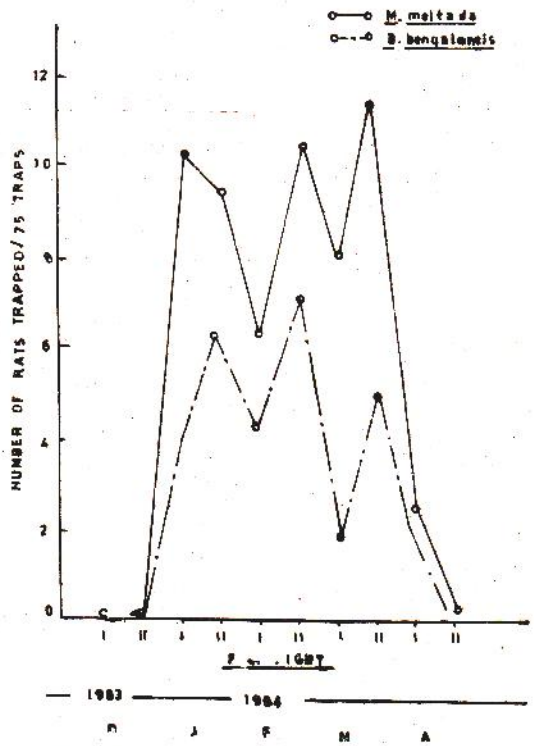


Fig. 2. Pogulation Dynamics of *Millardia meltada* and *Bandicota benqalensis* Trapped in Rabi crops.

during the second fortnight of February. The number declined after the harvest of the crop. It was further found that males outnumbered the females during the peak activity of both the species. The overall male-female ratio was 59.41 and 68.32 in *M. meltada* and *B. bengalensis*, respectively.

Seasonal activity of rodents in gram during 1992-93

The activity of rats (*M. meltada* and *B. bengalensis*) in gram crop is detailed in Table 5. The measure of activity was in the form of damage to the crop.

Table 5. Assessment of rat damage at different stages of gram crop during 1992-93

Period	Crop stage	Mean damage/m² (No.)	
		Branch	Pod
January	Vegetative	0.12 (0.33)	—
	Flowering	0 50 (1.25)	—
	Podding	2.75 (4.12)	15.86
	Seed formation	—	2.37
February	Seed	—	24.12
March	Pre-maturity	—	14.16

The activity of rats started from January at vegetative stage by cutting the branches. At flowering and pod initiation stage the branches were also cut during the month. The mean number of cut branches at vegetative, flowering and podding stage was 0.12, 0.50 and 2.75/m² respectively. At seed formation stage, the damage was confined mostly to pods rather than to branches in the months of January-February. At prematurity, the damage to pods was reduced as pods turned hard, during March. In brief, the population remained at peak during February and declined in March as the crop advanced towards maturity.

5 Rodenticidal Evaluation and Acceptability

The study on the testing of rodenticides was done under laboratory and fields. Under fields acceptability of some rodenticides was also recorded.

5.1 Laboratory Trials :

1. Under no choice test against *R. rattus rufescens* there was no difference in the kill of animals due to 2% zinc phosphide with or without drinking water in *ad libitum*.

2. Zinc phosphide with 1.75, 2.0 and 2.25 % and bromadiolone in concentration of 0.0025, 0.005 and 0.0075% were tested against. *R. rattus*. The results showed that zinc phosphide in each concentration caused cent per cent mortality in both the sexes. While bromadiolone with 0.0075% caused cent per cent mortality, the same rodenticide with 0.005% gave 100% mortality in male and 83.33% in female

rats. Bromadiolone (0.0025%) resulted in 50% mortality in male and 66.66% in females.

3. In order to find out the effective dose of bromadiolone 0.005% (wax blocks) @ 5, 10 and 15 g per animal were tested against *M. meltada*. The results showed that the rodenticide at the dose of 15 and 10 g/animal gave 100% mortality, while there was 66.66% mortality at 5 g level. The mean days to death were 5.53, 6.50 and 7.50 at 15, 10 and 5 g dose, respectively.

4. A study on the comparative bioefficacy of bromadiolone 0.005% (wax blocks) and Flocoumafen 0.005% (wax blocks) against *R. rattus rufescens* indicated that bromadiolone and flocoumafen registered 91.50 and 100% mortality within 11 and 4-16 days, respectively. When the rodenticides were used at the dose of 15 g/animal with exporure of 15 hrs.

5. Further Studies on bromadiolone (0.005%) and brodificoum (0.005%) wax blocks against adult and young groups of *R. rattus rufescens*, it revealed that at 10 gm dose/animal both the rodenticides caused 100% mortality within 11 days and which commenced 3rd day after poison exposure. The results further revealed that poison ingestion was found less in adults as compared to young ones.

6. Under choice test the rodenticides namely, bromadiolone 0.005%, flocoumafen 0.005% and cholecalciferol 0.075% wax blocks at the dose of 15 g/animal along with wheat, as alternate wheat food were evaluated against *M. meltada*. The rodenticides were exposed for 24 hrs. The results showed 25, 25 and 27.50% mortality with bromadiolone, flocoumafen and cholecalciferol, respectively. The mean days to death were 6, 7 and 3.0 in respective treatments.

5.2 *Field trials*

1. Field evaluation of 2% zinc phosphide, aluminium phosphide tablets (3 g) and 0.005% bromadiolone caused 86.16, 96.13 and 99.65% reduction of burrows, respectively in sugarcane crops.

2. A comparative efficacy of bromadiolone (0.005%) and flocoumafen (0.005%) wax blocks, indicated their equal effectiveness in burrow reduction in rice fields. The cumulative acceptability of bait after 3 days was 90% and 100% with bromodiolone and flocoumafen, respectively.

3. Investigations were made continuously for two years for the evaluation of different rodenticidal baits against field rats in wheat crop. The rodenticides were applied two times, one at flowering and other at milky grain stage. All the treatments (Table 6) had equal number of baits/replicate. For judging the efficacy, observations on the number of cut tillers were recorded before the treatment and at harvest.

Table 6 Evaluation of different rodenticides for the control of field rats in wheat crop (pooled data of 2 years)

Treatments	Cut tillers (%)		Reduction (%)
	Pre-treatment	Post-treatment	
Bromadiolone, 0.005% wax blocks	3.22 (8.70)	3.36 (9.50)	62.28
Flocoumafen, 0.005% wax blocks	1.61 (5.92)	2.00 (6.89)	77.55
Zinc phosphide, 2% (grain bait)	2.23 (5.26)	0.88 (4.88)	90.12
Zinc phosphide, 2% (semi-wet bait)	1.45 (4.44)	2.67 (8.29)	70.03
Control (untreated)	4.23 (9.42)	8 91 (16.80)	
SEm	1.84	1.15	
CD (p = 0.05)	NS	4.38	

Note : Figures in parentheses are arcs in transformed values

Pooled data of both the years revealed that all the rodenticidal treatments significantly reduced the incidence of rat damage in the experimental fields. Zinc phosphide, 2% (grain bait) proved significantly more effective than bromadiolone 0.005% in minimising the damage.

4. Two rodenticides, namely, flocoumofen, 0.005% and cholcaliferol, 0.075% wax blocks were evaluated on burrow count basis. They were placed continuously for 3 days. The data recorded after 6 days of application denoted 75.67 and 88.57% live burrow reduction in the respecive treatments. Thus flocoumafen proved superior over cholecalciferol in the control of rats.

5. Three rodenticides viz. flocoumafen 0.005% wax block, bromadiolone, 0.005% wax block and zinc phosphide, 2% solid bait, were evaluated on similar lines, i.e. burrow count basis. In these test, flocoumafen, bromadiolone and zinc phosphide caused respective reduction of 72.68, 53.77% and 61.50% live burrow count.

5.3 *Evoluation of schedule on the management of rodents*

(i) *Soybean crop*

A replicated field trial was conducted to develop schedule for the management of rodents in soybean. The results showed that all the treatments were significantly effective over control in reducing pod damage in soybean crop (Table 7). The combined treatment of using snap traps and 2% zinc phosphide at seed formation stage had the lowest number of damaged pods but was at par with the bromadiolone and 2% zinc phosphide (twice). Thus the application of rodenticide at seed formation was found to be the suitable stage for rodenticidal application in reducing rat damage in soybean crop.

(ii) Gram crop :

For determination of proper crop stage for the application of rodenticide, a replicated trial was laid out with 3 treatments for the control of rodents in gram crop. Only one application of 2% zinc phosphide was used at different stages of the crop growth.

Results of the trial revealed that the application of rodenticide at pod stage caused significantly less number of damaged pods as compared to the treatment applied at seed stage and in control. The application of rodenticide at seed stage was not found very effective. This is further supported by the fact that acceptibility of rodenticide was found less at seed stage (55%) as compared to pod stage (85%).

Table 7. Field efficacy of different treatments in the control of rodents in soybean crop

Treatment	Crop stage	Number of damaged pods/m²
Zinc phosphide 2% (Twice)	Pod + Seed formation	2.00 (1.49)
Zinc phosphide 2% (Once)	Pod	5.00 (2.32)
Bromadiolone 0 005% wax blocks (Once)	Seed formation	1.5 (1.38)
Snap trap + 2% Zinc phosphide	Seed formation Seed formation	0.52 (0 92)
Control	—	8.25 (2.85)

S.Fm = 0.26, C.D 5% = 0.50

Figures in parantheses are $\sqrt{X + 0.5}$ transformed values

6. Management of Rodents in poultry farms

6.1 Assesment of losses :

Studies made visually on the assessment of losses during 1983-84 it was found that on an average rodents caused annual loss worth Rs. 8744.33. This was based on the number of eggs eaten/destroyed, chick killed and feed stacks damaged by the rodents. In another study on feed loss due to rodents it was clear that a single *R. rattus* can consume 2.5 to 3.4 gm of poultry feed daily.

6.2 Preference for food :

Four different food materials were tested for the preference of *R. r. rufescens* in poultry. The data in Table 8 indicated that the wheat flour (Pill) was consumed to a greater degree by the rats and was found significantly more consumed as compared to the rest of the food materials. The next preferred food material was water soaked wheat and the consumption was significantly more than that of parched rice.

Table 8. Comparative consumption and preference of food by house rat in poultry.

Food	Mean consumption (%)
Wheat flour (Pills)	76.85 (63.14)*
Water soaked wheat	52.68 (46.36)
Wheat + *Gud* (1:10 ratio)	44.27 (41.30)
Parched rice	4.61 (7.94)
CD (P = 0.05)	15.69

*Figures in parentheses are arc in transformed values

6.3 Management of rodents by rodenticides in Poultry :

1. Application of warfarin (0.025%) for eleven days, caused 88.87% reduction in mixed population of *R. r. rufescens*, *B. bengalensis*, *M. musculus urbanus* and *S. murinus*.

2. Under pair 't' test a trial was conducted for the control of rats. There were two treatments in which one was treated with 2% zinc phosphide and other left untreated. The mean percent food consumption in treated shed was significantly (t=4.40) less (44.63%) as compared to untreated (62.92%).

In another trial with 2% zinc phosphide applied at monthly and once in two months interval resulted in 25.48 and 46.41% reduction in food consumption over control respectively. The mean food consumption was 82.48% in control.

6.4. Performance of traps

Comparative performance of two traps namely glue and wonder was studied on the trapability of rats in poultry. The data showed that wonder traps proved significantly better than that of glue traps in catching *R. rattus*. The mean trapped population was 3.11 and 0.77 in wonder and glue trap, respectively. The glue traps were also found physically damaged by rats.

7. Reproductive Biology of *R. r. rufescens*

For study of reproductive biology of *R. rattus* the sample animals weighed from 55.0 to 224.60 g. The males remained fertile from April, 89 to March, 90. The percent male fertility ranged from 28.57 to 93.75%, with maximum fertility during, March. The testis size varied from 1.20 x 0.30 cm to 3.90 x 1.90 cm in the sampled population.

The percentage of pregenancy varied from 21.73 to 63.15% during the study period. It was found highest during April, followed by May and February. The ovary size ranged from 0.20 x 0.10 to 0.70 x 0.60 cm.

8. Food preferences of three species of murids in wheat fields :

In a replicated field trial two foods viz. wheat and gram were tested in their dry and moist form (water soaked) for establishing preferences of *B. bengalensis, M. meltada* and *M. budooga* in field at prematurity stage of the crop. All the four foods were kept close to each other at a point.

Table 9. Food preference of field rats in wheat crop.

Food	Mean consumption/bait point (g)
Wheat (Dry)	0.00
Gram (dry)	0.75
Wheat (water soaked)	4.63
Gram (water soaked)	4.28
CD (p = 0.05)	1.98

The data showed that moist food material was preferred more than that of dry food. The water soaked bait of wheat and gram was consumed significantly more over their dry forms, even in the presence of naturally available food in the field (Table 9).

9. Performance of sampling methods in the assessment of rodent damage

In order to standardise the sampling methods for assessment of rodent damage, preliminary studies were conducted to test the performance of two methods in measuring the rodent damage. In both the methods same number of units/sample were observed in recording rat damage the data so obtained are given in Table 10.

Table 10. Comparative evaluation of two sampling methods in the assessment of rodent damage in crops.

Sampling methods	Mean no. of cut tillers/m²		Mean no. of damage pods/m²	
	Paddy	Wheat	Gram	Soybean
Diagonal	2.90	6.86	2.99	11.19
Stratified	1.40	4.00	5.00	5.01
't' value at 5%	2.41	NS	4.12	2.65

Looking to above table it can be said that the mean rodent damage was significantly more in diagonal than that of stratified method of sampling the plants in paddy, wheat and soybean at peak activity of pest. But in case of gram, the rodent damage measure was higher in stratified sampling method as compared to diagonal. The above findings are the results of first year observation and need confirmation on large scale.

10. Social Engineering Activity on Rodent Control

Social engineering activity on rodent control includes testing of rodent control technology and its motivation in the adoption through demonstration and training. The ultimate aim is to improve the agricultural production by reducing losses caused

by rodents. At this centre, 12 villages have been covered under the above studies so far.

Data gathered till date, have been pooled and summarised in the table 11. In case of maintenance areas in which control operations are done during crop seasons of the year have been pooled and mean has been worked out for each year. On the basis of pooled data, it is seen that under field conditions the number of live burrows in pre control census ranged from 0.90 to 21.25, 0.0-20.90 and 0.22 to 28.20/ha in maintenance, neglected and survey area, respectively with mean of 10.16, 11.26 and 12.11/ha, in above respective areas. This showed low to medium activity of rodents. The control success obtained, ranged from 68.76 to 98.80% in maintenance and 25.00 to 92.8% in neglected area. The mean control success was 84.37 and 51.21% in fields under maintenance and neglected area, respectively. Thus, area treated in both the seasons had higher percentage of control success.

In residential premises (houses) the rodent population ranged from 0.10 to 3.38, 0.05-4.87 and 0.10 to 4.0/house before the treatment in maintenance, neglected and survey areas, respectively. The low catches/house was due probably to the efficiency of wonder traps. The use of rodenticide, resulted in mean control success of 68.76 and 41.76% in maintenance and neglected area. With same rodenticide, the control success varied from one village to another village.

The present study revealed obvious effect of rodent control technology in reducing the rodent activity practically after the harvest of the crop. But the damage continue in the crops as farmers always neglected the use of demonstrated technology. They always expected free supply of rodenticides at peak rodent activity in crops or houses.

Table 11. Social engineering activity on Rodent Control (1983-92)

Data	Area	Habitat					
		Field			House		
		Live burrow census/ha (%)		Control success	Animal No./house		Control success %
		Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
Range	Maintenance	0.90 to 21.25	0.15 to 3.34	85.93	0.10 to 3.38	0.00 to 0.16	31.81 to 95.20
	Neglected	0.0 to 20.90	0.0 to 7.50	25.00	0.05 to 4.87	0.0 to 1.77	0.0 to 80.00
	Survey	2.22 to 28.20	—	—	0.10 to 4.04	—	—
Mean	Maintenance	10.16	1.21	84.37	0.69	0.06	68.76
	Neglected	11.28	1.37	51.21	0.89	0.29	41.76
	Survey	12.11	—	—	0.99	—	—

Coming to the second part of social engineering, the training was imparted to number of farmers in adopted villages, excluding the farmers attending the Kisan Mela or persons visiting the section. The dissemination of control technology through radio talks, newspapers and literature have been found to be effective source of motivation for adoption of measures against rodents. This resulted in use of rodenticides by farmers in wheat, soybean, sugarcane and mung beans.

Indian Institute of Sugarcane Research, Lucknow

This centre was sanctioned during Sixth Five Year Plan and started functioning from November 1984 with the joining of scientific staff. The centre was located at Sardarnagar Distt. Gorakhpur (U.P.) with a specific mandate of conducting research on various aspects of ecology and managements of rodent pests of Sugarcane-Wheat Mustard cropping systems of Uttar Pradesh. Besides these studies, the centre selected one more sugarcane growing zones in U.P. i.e., Simbhaoli (Ghaziabad) for conducting Social engineering activity on Rodent Control. Salient features of the progress of research at this cooperating centre is detailed as under.

1. Species composition of rodents

The state of U.P. is subdivided in ten agroclimatic zones and the major thrust of the centre has been in the North eastern plains of U.P. comprising 7 districts viz., Deoria, Gorakhpur, Maharaj ganj, Siddhartha Nagar, Basti, Gonda and Bahraich. These districts are very important from the point of sugarcane cultivation. Survey of rodent pests to various crops has been restricted to upland, lowland and *Bhat* (Calcareous) soil areas. The information collected during last 7-8 years indicated predominance of *Bandicota bengalensis* followed by *Mus booduga. Rattus meltada* and *Tatera indica.* The bandicoot alone represent 57.14-77.11% of total pest population. In the *Bhat* soil areas *T. indica* takes over the second position. This gerbil occurs in appreciable numbers in upland areas but in low and it shows stray occurrence. (Table 1). The metads (*R. meltada*) is in third position in all the three study areas

Table 1. Specific composition and burrow density of rodents in north eastern plains of U.P.

Study Area	Per cent occurrence of species				Live burrow counts/ha
	B. b.	*M. b.*	*R. m.*	*T. i.*	
1. Upland crop field	57.14	21.42	7.14	14 28	29.60
2. Lowland crop field	77.11	18.62	5.26	**	19.70
3. *Bhat* soils	61.90	14.20	4.76	19.04	28,20

** Stray occurenee; *B. b* = *B. bengalensis*, *M.b.* = *M. booduga*, *R m* = *R meltada* and *T.i.* = *T. indica.*

(4.76-7.14%). The burrow density per hectare is highest in upland crop fields (29.6) closely followed by *Bhat* soils (28.2) and lowland crops fields (19.7). Cropwise species composition, relative abundance and seasonal prevalence of major rodent pests is detailed in Table 2.

Table 2 : Seasonal prevalence of live burrow intensity in different crops of Sardarnagar (U.P.)

Months	Burrow intersity						
	Sugarcane	Rice	Wheat	Wheat mustard	Fallow land	Metalled channel	Houses
January	+++		+++		++	+	+++
February	+++		+++	+++	+	+	+++
March	+		+++	+++	++	+	+++
April	+		++	+++	+	+	+++
May	+		++	++	+	+	+++
June	+				+	+	+++
July	+	+			+	+	+++
August	+	+			+	+	+++
September	+	+			+	+	+++
October	++	+			+	+	+++
November	+++	+++	+	+	++	+	+++
December	+++				+	+	+++

Index :- + = Low ++ = Medium +++ = High,
Blank - Not applicable

2. Population dynamics of *B. bengalensis*

2.1 *On bunds* :

Thick and permanent bunds around crop fields play an important role in rodent pest ecology because these bunds serve as a breeding and safe shelter sites for the fossorial rodents. The data on live burrows on bunds showed an increasing trend with thickness of bunds upto 1.5m thickness. Live burrow counts per 50m bunds (liniar) on bunds of 0.5; 0.51-1.0m and 1.1-1.5m were 0.78, 1.55, 1.83, respectively. The studies on live burrows of *B. bengalensis* during 1990-91 revealed least burrow density on bunds during March and April. This indicates the migration of bandicoots to the maturing *rabi* crop fields. Since in the monsoon months the fields are mostly water logged these rodents get safer living on bunds registering higher burrow density during July-September. The burrow density on such bunds maintain its increasing towards during winters also (highest in Nov-Dec.) when the temperature is very low and the fields are irrigated for growing *rabi* crops.

2.2 In wheat fields vis a vis sugarcane fields :

The standing sugarcane crop influences the population build up of *B. bengalensis* in wheat fields. The data on live burrow counts and extent of damage indicate that wheat fields with sugarcane crop nearby harbour significantly higher rodent populations than the wheat fields having no sugarcane crops nearby (Table 3).

2.3 *Other crop fields* :

In rice fields, the population of pest rodents was recorded to be lowest at early stage of the crop growth and increased with the earhead stage and continued

Table 3. Influence of Sugarcane on infestation of *B. bengalensis* in Wheat fields.

Parameters	Wheat fields	
	With sugarcane (1)	Without suarcane (2)
Live burrow counts/ha	25.13*	9.40*
Damage (%)	2.63*	9.91*
Fields infested (%)	25.66*	12.33*

* 't' value between (1) and (2) significant at 1% level.

up to maturity stage. In mustard, wheat and mustard + wheat fields, the rodent activity followed similar trends of rice. Seasonal variation in the pest population indicated major aggregation in Feb-March, and November in wheat and rice crops, respectively. In the fallow lands and metalled channel, higher activity was noticed in June and November.

2.4 *In residential areas*

The data for last five years indicated higher rodents activity throughout the year with slight increase in rainy season. *R. rattus, M. musculus* and *B. bengalensis* were major rodent pests in this habitat.

3. Reproductive Biology of rodent pests :

3.1 *B. bengalensis*

Available data revealed maximum pregnancy during September month. No pregnancy could be ascertained during extremely hot and cold months of June and January respectily. The sex ratio was balanced. The average litter size was recorded as 5.56 and 6.25 per pregnant female in different years. The left uterine horn was observed to bear more number of embryos than the right. The average weight of ovary was 12.71 mg (range : 1.6-63 mg) and 19.8 mg (range : 2.7:71.0 mg) whereas the mean testes weight was 641 mg (range : 17-1213 mg) and 447 mg(217-1011mg) in different study years.

3.2 *R. rattus*

The pregnancy records revealed round the year breeding of this commensal rodent except in October-November with peak in September. The sex ratio was balanced. The average litter size was 6.06/female. The mean ovarian weight was 10.47 mg (range : 1.0-33.0 mg) and that of testis was 531 mg (range : 10-1613 mg) during first year of study and 678 mg (range : 42-1123 mg) in second year.

4. Assessment of damage

4.1 *Sugarcane* :

The study was carried out for four years on 90 local farmers field around Sardarnagar belonging to different varieties viz., Co 1149, Bo 91, Cos 7918, Cos 8315

Coj 64, Cos 802, Cos 770, Bo 54 and Co 1158. Of these, however, only four could afford varietal comparison. It was observed that lodged canes were more damaged than the standing canes with highest infestation in Co 1148 followed by Cos 7918, Bo 91 and Cos 8315. The infestation in plant and ratoon crop of Bo 91 was 0.56 and 0.80%; respectively indicating higher infestation in ratoon crops. Frequency distribution of damaged canes at different internodes revealed damage upto 9 inter nodes in severe cases and that again more than 50% of the damaged canes had damage only upto 2 internodes. Total loss in yields was higher in lodged canes (5.21 q/ha) than the standing canes (0.84 q/ha) in 1989-90. The individual damaged canes weighed on an average 20% lesser than the healthy canes. In another study the the total loss in yield amounted to about 2 82-4.65 q/ha in standing canes and 11.11-22.02 q/ha in lodged canes. The sugar recovery in the damaged canes was also reduced by 9.55 - 16.0%.

The damage to sugarcane in relation to crop maturity was also studied. Data on damage were collected from 15 local fields at the time of harvesting during each months from November to April. It was revealed that the damage gradually increases from November (0.22%) to January (2.13%) with maximum during January and then remains stable thereafter upto March. In April, it declined, possibly due to the fact that highly damaged fields are generally harvested earlier.

4.2 *Wheat*

Damaged data for last six years indicated that more than 50% (as high as 88.6%) of the fields were infested with rodents causing 8-10% damage to the wheat crop. The yield loss was between 2.56-5.73 q/ha.

4.3 *Rice* :

Of the various rice fields observed during last 7-8 year, 33.3-88.7% of the fields were found to be infested by rodents. Least damage of 0 44% was recorded in 1985-86 causing 0.34 q/ha yields loss. However, in subsequent years the yields in the loss was higher range of 0.98 - 2.13 q/ha.

4.4 *Mustard* :

Of the three crops discussed above mustard appeared to be least preferred. Thus the losses due to rodents remained in the range of 99.2 g to 9.1 kg/ha. Thus rodents proved practically of little significance to mustard.

4.5 *Crop preference of rodents* :

Sugarcane appeared to be most preferred crop in February by mustard+pea, wheat+mustard, Lineseed + lential, *Arhar*, *Tori* potato and tomato in descending order. In April, of the two available crops, wheat was most preferred. In Oct. - Nov,

again sugarcane was most preferred crop, followed by rice, *Arhar* groundnut and *tori*. In a mixed crop of mustard+wheat (in *rabi*), wheat was more preferred.

4.6 *Rapid method for estimation of rodent infestation* :

Correlation studies have shown that the percent rodent infested area of a field i.e., area under burrowing over the total area of field after the harvest, can be used as a criterian for the relative estimation of rodent infestation in this region. This has led to evolve a rapid method for estimation of rodent infestation during surveys.

4.7 *Hoarding losses by B. bengalensis* :

The burrows excavated after wheat harvest revealed an avcrage of 245 gm of unthrashed wheat hoarded per burrow which ranged from 25-609 gm/burrow.

5.0 Evaluation of new rodenticides

The rodenticides viz., bromadiolone and flocoumafen were evaluated in crop fields and residential premises for their efficacy against rodent pests. Both the poisons are single dose anticoagulants. Two formulations viz., loose bait and wax cakes of bromadiolone were tried, The control success on the basis of burrow count was 92.50 and 89.15% with loose bait (in two trials) and 79.54 and 82.29% with wax cakes. In the residential areas, the success with bromadiolone loose bait was above 95%. Flocoumafen (0005%) wax cakes too yielded 93.75 and 109% control of rodents in field and residential premises, respectively. Thus, both the anticoaguant were found to be promising for the region.

Attempts have also been made to work out rodenticidal application schedules in sugarcane crop. The studies revealed maximum reduction in rodent damage by single broadcast of bromadiolone loose bait followed by other treatments (Table 4)

Table 4. Efficacy of different rodentical schedules in sugarcane around Sardarnagar (Gorakhpur).

Treatments	Av. no. of damaged canes out of 300 canes)	% reduction over control
Bromadiolone cake : Double broadcast	11.00	66.32
Bromadiolone loosebait : Single broadcast	4.66	85.11
Bromadiolone loosebait : Double broadcast	13.66	58.76
Zn_3P_2 Flour balls broadcast followed by bromadiolone loose bait broadeast	11.66	64.38
Zn_3P_2 loose bait broadcast followed by bromadiolone loose bait broadcast	6.33	80.e1
Control (No treatment)	32.66	—

6. Bait preferences of *B. bengalensis*

Five food grains, viz., wheat, rice, bajra, grain and peas as whole grain, crack or flour were tested along with two edible oils viz, mustard and sesame in various combinations as additives with sugar and salt. Among various preference orders, rice flour + 10% sesame oil + 1% sugar appeared most preferred bait for the bandicoot followed by Rice flour + 10% sesame oil. The food preferences for the orther test baits are detailed in table 5.

Table 5. Food preference trials of *B. bengalensis*.

Treatments	ADI (Mean)
Rice flour+10% sesame oil	3.68
Bajra whole grain+2% sesame oil	1.35
Bajra flour	2.69
Rice whole grain	1 26
Bajra cracked+2% sesame oil+1% salt	1.26
Rice flour+10% sesame oil+1% sugar	4.11
Bajra whole grain+sesame oil+1% salt	1.32
Brjra roasted	0.12
Bajra craeked	2.92
Bajra whole grain	1.48

7. Social Engineering Activity on Rodent Control

This activity was initiated by the centre during 1985-86 with large scale control operation each year in Maintenance area and once in Neglected area. However, a third area called Survey area was not treated for comparison purposes. Upto 1988-89, control operations in fields were done under scientific supervision in fields with zinc phosphide (2%) baiting (after 2 days prebaiting) followed by aluminium phosphide fumigation. However in residential areas, warfarin baiting was done. The control success in these areas was from 85.4-94.38% in fields and 52.38-72.4% in residential areas. Later on the treatment were given of Zn_3P_2 followed by bromadiolone (in fields) and bromadiolone only (in houses). The control success in fields was over 90% whereas in houses it was 73.59 to 81.8%. This control of the rodents has brought about substantial reduction in damage to different crops showing marked effect on the control operation (Table 6). The farmers have also accepted the merit of the technology and are quite impressed.

Table 6. Effect of rodent control operation on the damage to major crops in 1989-1990.

Crop	Damage (%)		% reduction
	Maintenance area	Survey area	in damages over control (Survey)
1989			
Rice	0.64	1.55	58.70
1990			
Wheat	0.43	1.77	75.70
Sugarcane	1.17	4.08	71.32
Rice	0.78	1.69	53.84

Earlier the social engineering activity was restricted to farmers' fields around Sardar Nagar and under farm conditions in Govind Sadan farm, Sardarnagar. Under the farm conditions, the same technology yielded 96.13% control of fields rodents. The rodent pest complex of this farm comprised of *B. bengalensis* (40%); *R. meltada* (20—); *T. indica* (22.5—); and *M. booduga* (17.5—). During subsequent years the social engineering work was extended to Western U.P. near simbhaoli (Ghaziabad Distt.) Adoption of the above management schedule (of rodenticides) resulted upto 94.2% control success in the farmers fields. During 1988-89, the damage to sugarcane and wheat was 2.96 and 1.50% in maintenance area respectively, which was as high as 13.19 and 11.81 percent in survey area, respectively.

Under this activity, besides practical demostration at farmers fields, regular trainings were also imparted to the farmers and government officials.

Andhra Pradesh Agricultural University, Maruteru

Maruteru centre was sanctioned by Indian Council of Agricultural Research during VI Five Year Plan, but the research work could be initiated in 1985-86 with the joining of scientific staff. The centre has been entrusted with following mandates:

(i) Survey, collection and identification of rodents in all ecological zones of Andhra Pradesh

(ii) Burrowing and hoarding behaviour of field rodents in rice crop

(iii) Evaluation of rodenticides against major rodents

(iv) Assessment of rodent damage in rice and other crops

(v) Evolution of viable rodent management technology for rice and rice based cropping systems in Andhra Pradesh

(vi) Social engineering activity on rodent control.

Salient findings of this cooperating centre are summarised here under :

1. Species Composition

The State of Andhra Pradesh is divided in seven agroecological zones on the basis of rainfall patterns, soil type and cropping practices. They are : North Coastal Zone, Krishna, Godawari zone, Southern zone Scarce rainfall zone, Northern-Telengana zone, Southern Telengana Zone and High altitude zone. Rodent surveys have been done in two zones i.e , Krishna-Godavari and Southern zones.

1.1 *Rice* :

Rodent surveys in rice fields in Nellore, Baptala and Narsapur Divisions revealed predominance of lesser bandicoot rat, *B. bengalensis* and field mouse, *M. booduga.* The bandicoot constituted 78 and 86 per cent rodent population in Nellore and Narsapur Divisions, respectively, whereas, the field mouse was predominant in Baptala Division (59%). The sex ratio of bandicoots was almost equal, whereas, males of *M. booduga* were observed in higher numbers than the females (Table 1).

Table 1. Species and sex composition of two rodent species.

Divisions	Species composition (%)		*B. bengalensis*		*M. Booduga*	
	B. b.	*M.b.*	Male	Female	Male	Female
Nellore Division	78	22	50	50	63	37
Baptala Division	41	59	57	43	73	27
Narsapur Division	86	14	52	48	65	35

In an earlier study regular trapping from December 1985 to June 1987 at ARS Maruteru revealed these two rodent species in both *rabi* and *kharif* rice crop. The *M. booduga* dominated the rodent composition upto March 1987 (more than 50%) and later only *B. bengalensis* was trapped.

1.2 *Rice fallow pulse crops* :

In certain areas viz,, Tenali and Guntur districts, pulses, like green and black gram are cultivated in rice fallows after *kharif*. The moist seeds are broadcasted in standing rice crop, just few days before the harvest. With the available residual moisture and fertility, pulse crop is cultivated without incurring much expenditure. In these pulses too *B. bengalensis* was the major rodent pest. However in East and West Godavari districts of Coastal Andhra Pradesh *M. booduga* was also encountered along with lesser bandicoot in the pulses.

1.3 *Coconut* :

The nurseries of coconut were observed to be inhabited by *B. bengalensis*, *M. booduga* and *T. indica*. In the coconut planations, only one species (*Rattus rattus wroughtoni*) was observed as major pest.

2. Infestation patterns

Monthly collections of rodents at ARS Maruteru for two years indicated highest trap index of 41.39 and 30.0/100 trap/24 hours during December 1985 and January 1986, respectively. During rest of the months, it was below 20.0 except in July 1986 when it again rose to 24.13. Minimum trap index of 1.80 was recorded in the month of February, 1987. Further probe into data revealed generally poor trap indices from January-April (less than 5.10), wheseas, it was between 11.0-24.13 during June-December 1986. In the pulse crops, the infestation of *B. bengalensis* follow an increasing trend from early stages to maturity stage. At seedling stage mean number of live bandicoot burrow per hectare was 14.20 which increased to 33.20 at vegetative stage and then to 51.95 at maturity stage.

3. Assessment of rodent damage

3.1 *Rice*

The rodent damage in rice was assessed at the time of harvest using tiller count method, Among the six villages where this study was conducted, Panditavillur and Kavitam recorded minimum (17.56) and maximum (21.23%) damage, respectively. In another study, two rice varieties viz., IR-64 and DPI-R35 were selected for understanding the actual yield loss by simulated damage under controlled conditions. In all seven types of simulated damages were studied. They were : (i) control main tillers and shoots intact), (ii) cutting all shoots, (iii) cutting all tillers except

the main shoot, (iv) cutting all tillers except the main shoot and one primary tiller, (v, vi and vii) cutting all tillers except main shoot and 3, 5, 7 tillers, respectively. In both the test varieties, reduction in grain yield was observed which indicated that loss in shoots at any stage of the crop leads to reduced grain yields (cutting of tillers at flowering stage has more detrimental effect on yield (46-100% loss) than at panicles initiation (33-88% loss) and at tillering stage (10-58% loss).

3.2 *Pulse crop* :

Observation on yield attributes of blackgram (no. of plants/sq. meter no. of pods/plant; no. of seeds/pod); no. of live burrows/ha, no. of damaged pods) in randomly selected 50 fields (33.29 ha) revealed an estimated yield loss of 48 kg grain per ha or 0.93 kg grain/burrow, amounting to about 11.0% loss.

4. Rodent behaviour

(i) Cannibilistic behaviour of *B. indica*, *B. bengalensis* and *T. indica* towards their youngones immediately after delivery was observed in the laboratory cages. In case of both the bandicoot species, the mothers were observed to be cannibilistic on the newly bornes. The mothers kill the pups by inserting incisors into the neck and then feed on them. In case of *T. indica*, the male parent was observed to feed on the youngones.

(ii) Burrowing behaviour of *B. bengalensis* was studied. The length of a burrow arm ranged from 0.7-4.0 m with a depth ranging between 24-25 cm and burrow diameter was 6-7 cm. On an average 377.4 g (maximum 2000 g) of cut stems, leaves, earheads of paddy were hoarded in the burrows.

5. Evaluation of Rodenticides

Field trials with zinc phosphide (2% loose bait, and ready to use baits of cholecalciferol (0.075%) and bromadiolone (0.005%) against *B. bengalensis* in rice crop revealed highest control success of 95% with bromadiolone followed by cholecalciferol (78%) and zinc phosphide (55%). The control success was comparatively reduced in another trial in two villages of Narsapur Division. In this study, two second generation anticoagulant viz., bromadiolone and flocoumafen were compared with zinc phosphide. The ready to use wax formulation of flocoumafen fared better than the other two test rodenticides (Table 2).

Rodenticidal evaluation in coconut palms were conducted against *R. r. wroughtoni* using bromadiolone (0.05%), brodifacoum (0.005%), Rodafarin (0.025%), zinc phosphide (2%), Thimet (2%) and Thimet (2%) + fish meal. The ready to use formulations of first three rodenticides (anticoagulants) yielded cent per cent reduction in plant, bunch and nut infestation by this rat. In the rest of the treatments, the per cent reduction in plant (64 5%), bunch (63.8%) and nut (56.5%) infestation were

Table 2. Effectiveness of rodenticides against *B. bengalensis* in rice.

Treatments	% control success			
	Based on burrow count		Based on tiller damage	
	Vill I	Vill II	Vill I	Vill II
Bromadiolone (0.05%) wax cake	62.06	65.17	69.48	63.42
Flocoumafen (0.005%) wax cake	74.51	68.02	71.17	73 34
Zinc phosphide (2%) loose bait	34.17	31.36	29.44	25.18

minimum in Thimet treatment and maximum (69.2, 82.7 and 63.8%) respectively in zinc phosphide treatment.

6. Social engineering activity on rodent control

Under this project, three areas viz., Maintenance, Neglected and Survey under rice cultivation were selected. In the maintenance area, where the control measures were followed under scientific supervision, the rodent damage in rice was only 1.38%. Whereas, in neglected area, where only training was imparted to the farmers, the damage to rice crop was slightly higher (5.72%). In the survey area, where neither education nor demonstrations were given to the farmers, the rodent damage was highest (24.5%).

Gujarat Agricultural University, Junagadh

The All India Co-ordinated Research Project on Rodent Control, Junagadh centre under Gujarat Agricultural University has been sanctioned by Indian Council of Agricultural Research, New Delhi in VII Five year Plan from April, 1987 to to evolve location as well as species specific strategies for rodent pest management. Besides multilocation research studies, this centre has been entrusted with specific areas of research in respect of groundnut crop on which greater emphasis is to be laid for evolving ecologically sound, economically viable and sociologically acceptable rodent management techniques. The staff at this centre was filled up from November, 1987 and the research work under this project was initiated afterwards. The research findings of various experiments conducted from 1988-89 to 1992-93 (Five years period) are summarized hereafter.

1. Rodent Species Composition

Extensive survey work is going on in various habitats viz., residential premises, godowns, poultry farm as well as crop fields of different agroclimatic zones of Gujarat State. The major rodent species found during the survey are *Rattus rattus* (Linnaus), *Rattus cutchicus* (Wroughton), *Mus musculus* (Linnaus), *Mus booduga* (Gray), *Millardia meltada meltada* (Gray), *Bandicota bengalensis kok* (Gray), *Tatera indica indica* (Hardwicke), *Meriones hurrianae* (Jerdon).

2. Infestation Patterns

2.1 *Residential premises, godowns and poultry farms* :

The commensal rats viz., *Rattus rattus*, *R. cutchicus* and *Mus musculus* were recorded in residential premises, whereas *R. rattus*, *R. cutchious*, *M. musculus* and *Bandicota bengalensis* were found damaging the stored products in godowns. Similarly, *R. rattus*, *R. cutchicus* and *B. bengalensis* also infested the poultry farms Amongst these species, *R. rattus* was found predominant in all these three habitats. The rodent activity was comparatively high, being 10.78 to 14.85 per cent in houses and 10.89 to 13.81 per cent in godowns during July-August, however it was minimum (2.97 to 3.80% in houses and 3.43 to 5.61 % in godowns) during the July-August, however it was minimum (2.97 to 3.80% in houses and 3.43 to 5.61% in godowns) during the month of September.

2.2 *Field survey* :

Field surveys were conducted in five different agroclimatic zones of Gujarat State viz., North Saurshtra, South Saurashtra, Bhal and coastal area, North Gujarat

dry region and North-West arid zone. The gist of survey and monitoring is given below and also depicted in Fig. 1.

The relative abundance of rodent species may vary with soil type, cropping pattern, irrigation facilities and other ecological conditions of different locations. The studies on the ecological distribution of rodents in five different agroclimatic zone revealed that *Bandicota bengalensis kok* was predominant comprising 49.92 to 72.20% per cent population followed by *Millardia meltada meltada* (15.04 to 37.94% and *Tatera indica indica* (1.41 to 26.30%) during *kharif rabi* and summer in almost all areas of South Saurashtra agroclimatic zone except in Jetpur, Rajula and Jafrabad taluka where *T. indica indica* was found predominant with 42.27 to 55.56 per cent of population. *Mus booduga* was also found damaging the crop fields in some pockets of this agorclimatic zone. *B. bengalensis kok* was also found predominant (48.04 to 55.75%) in North Saurashtra agroclimatic zone during *kharif* and *rabi* seasons and it was followed by *T. indica indica* (17.31 to 41.30%) and *M. meltada meltada* (8.14 to 26.93 %). Thus, *B. bengalensis kok* was found predominant species in majority of groundnut growing areas of South Saurashtra and North Saurashtra agroclimatic zones in Saurashtra region.

In *Bhal* and coastal areas agroclimatic zone, *T. indica indica* was found predominant species comprising 55.71 to 70.39 per cent of population in *kharif* seasons

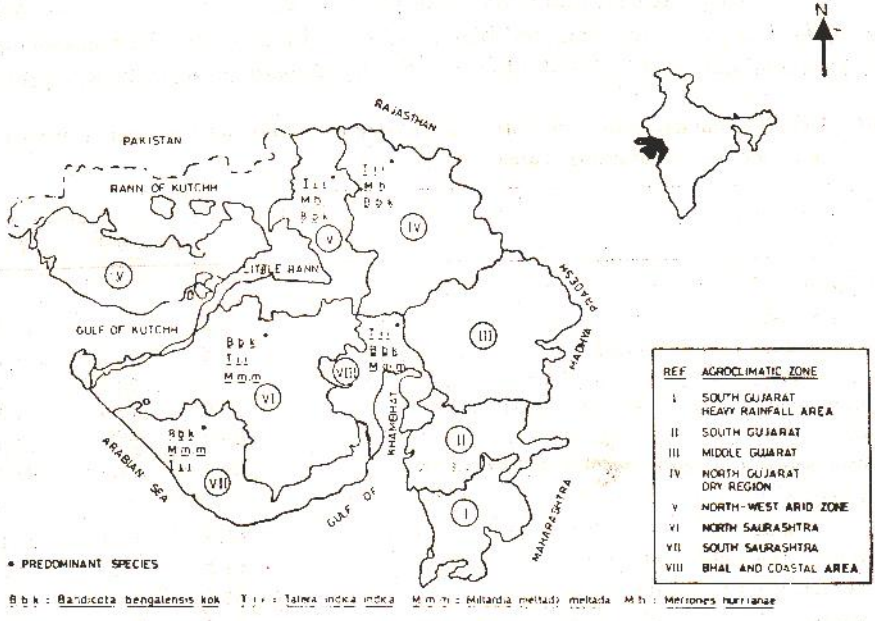


Fig. 1. Distribution of major rodent species in different agroclimatic zones of Gujarat state

except in Dholka and Dhandhuka talukas of the agroclimetic zone where *B. bengalensis kok* was found predominent with 67.81 per cent population which is due to deep black and salorthide soils of these talukas and it was followed by *B. bengalesis kok* and *M. meltada meltada* with population of 21.64 to 37.71 and 4.91 to 7.64 to 7.64 per cent, respectively.

The Indian gerbil, *T. indica indica*, was found predominant (68.54 to 82.85%) in North-West arid zone and North Gujarat dry region followed by *Meriones hurrianae* (17.15 to 33.28%) and in some pockets *B. bengalensis kok* and *M. meltada meltada* also followed. But in Semi Tharad and Vav talukas of North-West arid zone and Dhanera taluka of North Gujarat-dry region, *M. hurrianae* was found predominant species (78.20 to 82.85%) and it was followed by *T. indica indica.*

B. bengalensis kok was found to be predominant rodent species (Table 1) in almost all types of soil in groundnut growing area during *kharif* and summer season except in coastal alluvial+medium black+shallow black soil in *kharif* seasons and mixed red and black+shallow black soil in summer season. Other two species viz., *M. meltada meltada* and *T. indica indica* were fonnd to be the next in order of abundance in these habitats. During *kharif* season, the population of *T. indica indica* was found comparatively higher than *M. meltada meltada* in shallow black + coastal alluvial and shallow black type of soils. On the other hand, *T. indica indica* was found predominat species in cosatal alluvial+medium black+ shallow black type of habitat during *kharif* season and it was followed by *B. bengalensis kok* and *M. meltada meltada* (Table-1). In mixed red black + shallow black soil, *M. meltada meltada* (Table-1). In mixed red black+shallow black soil, *M. meltada meltada* was present in

Table 1. Relative abundance of field rodents accociated with groundnut in different types of soil in major groundnut growing area

Soil type	Per cent occurrence of rodent species.		
	B.b.k.[1]	*M.m.m.*[2]	*T.i.i.*[3]
Kharif season			
1. Medium black	58.2	24.5	17.3
2. Medium black+shallow black	68.5	20.4	11.1
3. Mixed red & black+medimum black	52.2	26.7	21.1
4. Snallow black+medimum black+coastal alluvial	54.9	17.9	27.2
5. Shallow black	40.2	25.3	34.5
6. Coastal alluvial+medium black+shallow black	40.0	11.3	48.7
Summer season			
1. Medium black	61.0	17.9	21.1
2. Medium black+hilly soil	61.5	23.3	15.2
3. Mixed red & black+medium black	63.6	31.8	4.6
4. Mixed red & black+medium black	42.2	55.0	2.8

1. *Bandicota bengalensis* 2. *Millardia maltada maltada*
3. *Tatera indica indica.*

relatively high number while, the other two species viz. *B. bengalensis kok* and *T. indica indica* were found comparatively lower in numbers during summer season.

Type of irrigation also played an important role in relative abundance of *M. meltada meltada* and *T. indica indica* in South Saurashtra agroclimatic zone. The Soft-furred field rat, *M. meltada meltada* was found higher in number than Indian gerbil, *T. indica indica* in the areas having canal irrigation facility, whereas the population of *T. indica indica* was comparatively higher than that of *M. meltada meltada* where the irrigation was done by wells during summer seasons.

3. Rodent damage in various crop

Sudden multiplication of rodents and their population assuming menacing numbers, happended in Gujarat State during the year 1975-76 and again in 1989-90. Rodent damage in field crops increased intensity from *kharif* 1988 to *rabi* 1989-90 and the extent of yield loss in one isolated field of groundnut surrounded by barren/fallow land was as much as 85.42 per cent during summer, 1989. Because of heavy damage due to rodent in *rabi* crops of 1989-90, farmers avoided showing the summer groundnut during 1990 in most of the groundnut growing areas of the Saurashtra region. Extent of rodent damage.

Table 2. Extent of rodent damage in major crops in Gujarat State.

Crop	Per cent damage				
	1988-89	1989-90	1900-91	1991-92	1992-93
Groundnut	4.26 to 9.97	2.90 to 28.13	3.25 to 6.86	2 82 to 6 53	4 49 to 10.51
Pearl millet	2.03 to 9.93	4.22 to 12.37	2.68 to 5.79	2.31 to 5.32	4.01 to 10.12
Sorghum	—	4.28 to 10.60	3.10 to 4.42	2.96 to 3.94	2.56 to 4.01
Wheat	6.16 to 16.79	10 88 to 20.92	2.11 to 17.14	3.79 to 7.74	2.71 to 6.07
Gram	3.88 to 10 67	7.45 to 24.98	2.31 to 6.32	3.99 to 6.32	4 45 to 6.39

The observations recorded during the survey from the year 1988-89 to 1992-93 further indicated that the per cent rodent damage was maize 2.68, paddy 8.25, in sesamum-3.15, soybean-4.95, green gram-1.21 to 11.11, black gram 2.19 to 4.04, in pigeonpea 5.89, cowpea 18.30, bean 1 12 to 18.46, cucumber 4.87 to 19.89, tomato 9.05 to 18.10, potato 1.73 to 6.95, sweet potato 2.0, chillies 3.45 to 11.65, carrot 11.24, bottlegourd 4.09, cumin 1.84, lucern 7.55 to 15.75, cotton 3.19 to 23.20, sugarcane 2.21 to 5.58 and coconut 6.15 to 12.82. The highest damage in all the field crops was recorded during the year 1989-90, when there was a severe outbreak of rodents. The rodent population was declined from *kharif*, 1990-91.

4. Population dynamic in groundnut crop :

Pop uiation dynamics of major rodent species in groundnut was studied from 1990-91 to 1992-93. The studies were conducted during *kharif* as well as summer

seasons by setting one hundred traps (sherman and bandicoot) in one hectare area. The results revealed that *Bandicota bengalensis kok* and *Millardia meltada meltada* were observed throughout the *kharif* season, whereas in summer groundnut, *M. meltada meltada* was observed from vegetative/flowering stage of the crop. The third species, *Tatera indica indica* was observed from pod formation stage to harvest of the crop in both the seasons. Thus, *B. bengalensis kok* was found predominant in both the seasons. The rodent activity was low at sowing/germination of the crop (5-10 rodents/100 traps/day in *kharif* season and 1 to 2 rodents/100 traps/day in summer season), however, it was increased from pod formation stage and was highest (24 to 31 rodents/100 traps/day in *kharif* season and 22 to 27 rodents/100 traps/day in summer season) at harvest stage of the crop. Similar trends were also observed in respect of burrow census during both the seasons. The male was found predominant over female in all three species in *kharif* and summer groundnut.

5. Reproductive biology

Observations of the various parameters viz.; juvenile, prepubartal and adult stage of male and female; prevalance of pregnancy and litter size of predominant commensal rat, *Rattus rattus*, were recorded during the year 1990-91 to 1992-93. Maximum juvenile stage in male (48.00 to 68.00 %) was recorded in the month of February and October, however, the maximum prepubartal stage (40.00 to 64.00%) was recorded during January, September and November: The males remained fecund (55.00 to 91.67%) from March to August and again in December. The maximum prepubartal stage in females (50.00 to 52.00%) was recorded in September and October. The results further revealed that 40.00 to 62.50 per cent females were in reproductive phase during March, July, August, November and December (Except November, 1990). The active reproductive period was seen during March to August and December (50.00 to 83.33%). Almost similar trends were also observed in respect of presence of embryos.

6. Laboratory evaluation of Rodenticides

Two different rodenticides viz., bromadiolone 0.005% wax cake against *Rattus rattus, R. cutchicus, Bandicota bengalensis, Tatera indica indica* and *Millardia meltada meltada* and cholecalciferol 0.075% wax block against *Rattus rattus, Bandicota bengalensis* and *Millardia meltada meltada* were evaluated by two days feeding with nochoice test in laboratory. In bromadiolone 0.005% wax cake, cent per cent mortality of *R. rattus R. cutchicus, B. bengalensis, T. indica indica* and *M. meltada meltada* was achieved in 10.4, 11.13, 7.8, 5.9 and 5.2 days, respectively with mean intake of active ingradient of 9.29, 6.21, 4.97, 8.28 and 7.40 mg/kg body weight. respectively. However; cent per cent mortality in *R. rattus, B. bengalensis* and *M. meltada meltada* was recorded in 6.0, 4.5, and 4.0 days with mean intake of active ingradient 83.25, 43.5 and 100.88 mg/kg body weight, respectively in cholecalciferol 0.075% wax block in these three species.

7. Rodent management :

7.1. Poultry farm :

Two existing rodenticides, viz., zine phosphide 2% poison bait and bromadiolone 0.005% wax cake (10 g/bait station) were evaluated for rodent pests management in poultry farm from the year 1988-89 to 1992-93. The house rat, *Ruttus rattus* was found predominant, while *R. cutchious* and *Bandicota bengalensis* were found comparatively low in population throughout the year. Among two existing rodenticides bromadiolone 0.005% was cake was found more effective as the reduction in trap line index and egg damage was higher than zinc phosphide 2% poison bait. Further, bromadiolone 0.005% was cake was found significantly superior as it registered 86.00 per cent (pooled values) round control success as compared to 70.67 per cent rodent control succes achieved in zinc phosphide 8% poison bait. Thus, among two rodenticides, bromadiolone 0.005% wax cake was found better as it gave significantly higher rodent conteol sucess and is also safer than zinc phosphide 2 % poison bait in poultry farm.

7.2 *Field crops* :

7.21 *Relative efficacy of existing and newer rodenticides* :

Four different rodenticides viz., bromadiolone 0.005% wax cake, cholecalciferol 0.75 % wax block, flocoumafen 0.005 % wax block and zinc phosphide 2% poison bait (each of 10 g/live burrow) were evaluated alongwith untreated control against field rodents in groundnut and wheat crops from the year 1929-90 to 1992-93. Further, comparative evaluation of bromadiolone 0.005% wax cake and loose bait, cholecalciferol 0.075% wax block (only in tomato) and zinc phosphide 2% poison bait (each of 10 g/live burrow) against field rodents in tomato and bean crops was carried out during the year 1988-89.

Groundnut :- Four years pooled data indicated that significantly lowest plant as well as pod damage at 9 days after first (0.92 and 1.17%, respectively) and second application (0 52 and 0.52%, respectively) of rodenticides and at harvest stage (0.83 and 1.00%, respectively) were recorded in the treatment of bromadiolone 0.005% wax cake. The live burrows were significantly reduced in zinc phosphide 2% poison bait at 3 days after application, however, bromadiolone 0.005% wax cake was found significantly superior in reduction of live burrows (0 88 to 5.57 live burrows/ha) at 5, 7 and 9 days after both the applications of rodenticides Significantly highest rodent control success (91.10%) and significantly highest yield of groundnut pod (1265 kg/ha) were also recorded in bromadiolone 0.005% wax cake and it was followed by cholecalciferol 0.075% wax block and flocoumafen 0.005% wax block in respect of reduction in crop damage, live burrows, control success and yield of groundnut pods (Fig.-2).

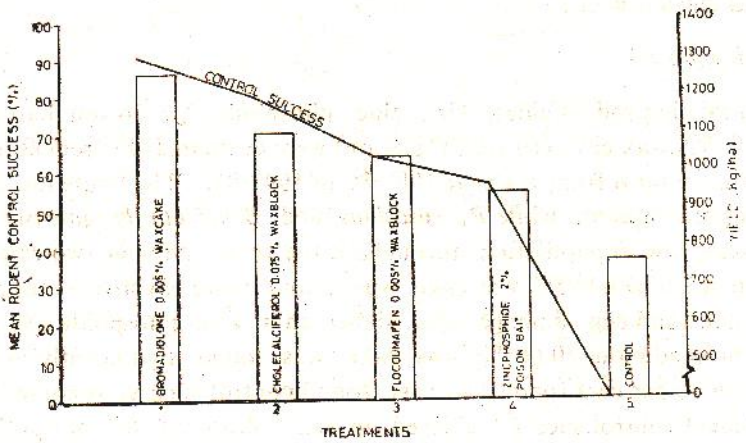


Fig.2. Relative efficacy of existing and newer rodenticides in groundnut

Wheat :- Bromadiolone 0.005% wax cake found significantly superior as it recorded the lowest earhead damage (0 53 to 0.90%) at 9 days after first and second application of rodenticides and at pre harvest stage of crop. Similarly, minimum number of live burrows (1.61 to 6.76 live burrow/ha) were also recorded in bromadiolone 0.005% wax cake at 5, 7 and 9 days after both the applications, however zinc phosphide 2% poison bait was found significantly superior in reduction of live burrows at 3 days after application of rodenticides. Significantly highest rodent control success (93.19%) and yield of wheat crop (4498 kg/ha) were also recorded in bromadiolone 0.005% wax cake (Fig.-3) and it was followed by cholecalciferol 0.075% wax block and flocoumafen 0.005% wax block.

Tomato :- Maximum reduction in plant as well as fruit damage (55.73 and 82.17% respectively) was recorded in the treatment of bromadiolone 0.005% wax

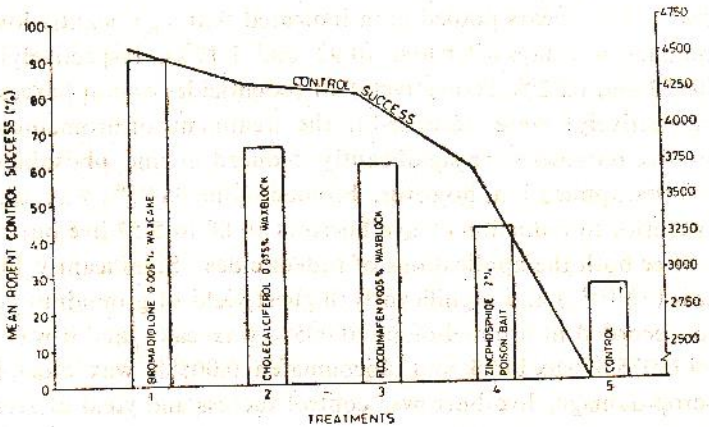


Fig. 3. Relative efficacy of existing and never rodenticides in wheat crop

cake and it was followed by bromadiolone 0.005% loose bait (47.19 and 80.96%, respectively), cholecalciferol 0.075% wax block (45.71 and 80.50% respectively) and zinc phosphide 2% poison bait (30.46 and 78.77%, respectively). Similarly, the highest rodent control success (84.22%) was also recorded in bromadiolone 0.005% wax cake while it was minimum (64.71%) in zinc phosphide 2% poison bait.

Bean . - Bromadiolone 0.005% wax cake was found most effective against field rodents ia bean crop as it reduced 71.89 and 88.91 per cent plant and pod damage, respectively. It also gave highest rodent control success (91.43%). however, it was followed by bromadiolone 0.005% loose bait and zinc phosphide 2 % poison bait in respect of reduction in plant and damage as well as burrow control success.

7.22 *Rodent managementi n barren land and its impact on rodent damage in cultivated area* :

Two identical barren/waste land areas surrounding the cultivated fields were selected. Among these two areas, both cultivated fields as well as its surrounding barren land were treated with rodenticides in one area, whereas only cultivated fields were treated and its surrounding barren land was kept untreated check in second area. The experiment was conducted during *kharif* and *rabi* seasons of the year 1988-89 to 1991-92.

The reduction in rodent population in cultivated fields was significantly higher (73.33 to 90.00%), when the rodenticides were applied in both cultivated fields and its surrounding barren land in comparison of the rodenticides applied only in cultivated field (66.67 to 80.00 %) during *kharif* and *rabi* seasons of 1991-92. In groundnut crop, significantly lower plant and pod damage (0.37 and 0.55 %, respectively at pod maturity stage and 0.76 and 0.81%, respectively at pre-harvest stage and higher yield of groundnnt pods (635 kg/ha) were recorded when the rodenticides were applied in both cultivated fields and its surrounding barren land than the rodenticides applied only in cultivated field during *kharif* 1991-92. Similarly, significantly lower plant damage in wheat crop i.e, 1.45, 0.23 and 0.91 per cent at tillering, milky and pre-harvest stage, respectively and significantly higher yield (3965 kg/ha) were recorded, when the rodenticides were applied in both cultivated fields and its surrounding barren land as compared to that of observed, when rodenticides were applied only in cultivated fields during *rabi* season of 1991-92. Similar trends in respect of reduction in rodent activity, crop damage and yield of groundnut and wheat in these two areas were also recorded in *kharif* and *rabi* season, respectively during the year 1989-90 and 1990-91.

Thus, the rodent management in barren land has great impact on the reduction in rodent activity as well as plant and pod/earhead damage and ultimately increase in yield of nearby groundnut and wheat during *kharif* and *rabi* season, respectively.

7.2.3. *Rodent management strategies* :

Two existing rodenticides viz., bromadiolone 0.005 % wax cake and zinc phosphide 2 % poison bait alongwith their combination were applied at different intervals in groundnut from 1989-90 to 1992-93 and in wheat and cucumber crop during 1992-93 to develop the rodent management strategies. However, these two rodenticides applied alternatively for rodent management in coconut orchard from 1988-89 to 1921-92.

Groundnut :- Four year pooled results revealed that two applications of bromadiolone 0.005 % wax cake @ 10 g/live burrow, first at flowering and second at pod maturity stage, was found more effective as it reduced 86.05 and 88.23 per cent rodent activity at flowering and pod maturity stage respectively. Similarly, significantly lower plant damage (0.74%) at flowering stage were recorded in this treatment. Thus, the highest reduction (82.95 per cent) in plant damage at flowering stage and 84.49 and 83.88 per cent reduction in plant and pod damage, respectively at pod maturity stage were also recorded in two applications of bromadiolone 0.005 % wax cake. The results further revealed that significantly highest yield of groundnut pod (1335 kg/ha), maximum cost benefit ratio (1 : 43:50) and maximum increase in yield over control (Fig. - 4) were also obtained in this treatment. However, it was followed by application of zinc phosphide 2 % poison bait at flowering stage±bromadiolone 0.005% wax cake at pod maturity stage with yield of 1162 kg/ha and 1 : 24.8 cost benefit ratio and zinc phosphide 2% poison bait at flowering stage+zinc phosphide 2 ... poison bait at pod maturity stage with the yield of 1063 kg/ha and 1 : 13.00 cost benefit ratio.

Thus, two applications of bromadiolone 0.005... wax cake, first at the time of flowering and second at pod maturity srage (cost benefit ratio 1 : 49.5) or first

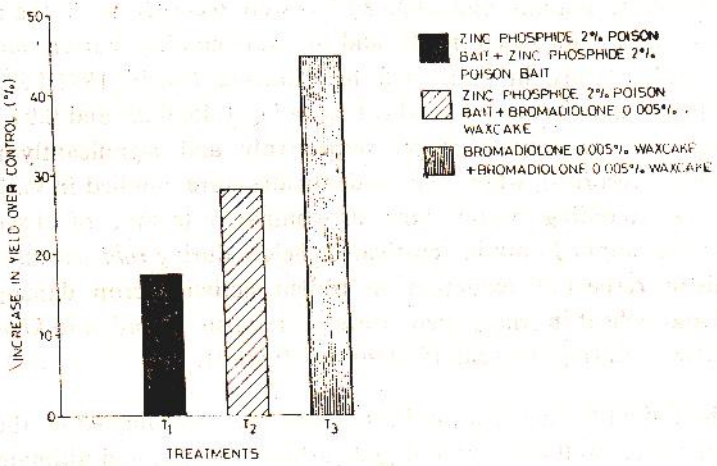


Fig 4 Percent increase in yield of groundnut pods over control

application of zinc phosphide 2 % poison bait at the time of flowering and second application of bromadiolone 0.005% wax cake at pod maturity stage (cost benefit ratio 1 : 24.8) each @ 10 g poison bait/live burrow are recommended for effective rodent management in groundnut crop.

Coconut :- In coconut orchard, application of bromadiolone 0.005 % wax cake @ 10 g/live burrow and 100 g/five crowns (coverep by domestic tiles bait station) at an alternate picking was found superior as it registered 87.77 to 91.70 per cent reduction in nut damage than zinc phosphide 2% poison bait applied in silmilar way in which the reduction in nut damage was recorded from 72.71 to 82.09 per cent. Thus, the bromadiol one 0.005% wax cake @ 10 g/live burrow and @ 100 g/five crowns at an alternate picking is found better for rodent management in coconut orchard.

Wheat and cucumber : - Zinc phosphide 2% poison bait and bromadiolone 0.005 % wax cake alongwith their combination evaluated in wheat crop during the year 1992-93 indicated that two applications of bromadiolone 0.005 % wax cake, first at the time of tillering stage and second at milky stage in wheat crop and first at 30 and second at 60 days after sowing in cucumber were found more effective in respect of reduction in rodent activity, crop damage and higher yield than the other treatments. This experiment will be continued for two or three years for its precise conclusion.

8. Evaluation of Different Traps

Four different types of traps viz., wonder trap, sharman trap, bandicoot trap and glue trap were evaluated for their effectiveness in trapping rodents species found in godown and poultry farm during the year 1988-89 and 1989-90. Among these traps, the glue trap was found comparatively more effective in trapping all the species of rodents viz., *Mus musculus*. *Rattus rattus*, *R. cutchious* and *Bandicota bengalensis* observed in godown and poultry farm. The percentage population trapped in godown and poultry farm were also highest (48.15 to 56.00... in godown and 61.76 to 62.96 ... in poultry farm) in glue traps during these two years. A comparision of four different type of traps further revealed that the glue trap was found significantly superior over rest of the traps as the highest number of rodents in a day, being 2.66 rodents/trap in godown and 3.78 rodenst/trap in poultry farm were trapped in glue trap. The remaining three traps i.e. wonder trap, sherman trap and bandicoot trap were at par in their effects with 0.55 to 1.03 rodents/trap in godown and 0.55 to 0.91 rodent/trap in poultry farm.

9 Social Engineering Activity

Three villages viz., Goladhar (maintenance area), Galiyawada (neglected area) and Majevadi (survey area) of Junagadh taluka were selected from 1988-89 to

1991-92 to compare the impact of transfer of technology by training and educating the farmers for rodent management under social engineering activity project. Four years pooled results are summerized here and also depicted in Fig. 5 & 6, in groundnut. The rodent activity was reduced up to 80.95 and 80.00 per cent at flowering stage and pod maturity stage, respectively in maintenance area as compared to 78.85 per cent reduction in rodent activity at flowering stage in neglected area. Similarly, 76.35 and 64.53 per cent reduction in plant damage at flowering and pod maturity stage, respectively and 67.20 per cent reduction in pod damage in groundnut crop at pod maturity stage were also recorded in maintenance area. However, the rodent activity and crop damage were found higher at pod maturity stage in neglected area and both at flowering and pod maturity stage in survey area. Significantly highest groundnut pod yield (1114 kg/ha) was also recorded in maintenance area (Fig. 5) and was followed by neglected area.

The results further revealed that 77.62 and 86.80 per cent reduction in tiller/earhead cut damage was recorded at tillering stage and milky stage, respectively in wheat crop in maintenance area, whereas 69.57 per cent reduction in tiller cut damage was observed at tillering stage of wheat crop in neglected area and there after it was increased as the control operation was not carried out after this stage in neglected area. The reduction in rodent activity in wheat crop was 78.57 and 87.50 per cent at tillering and milky stage, respectively in maintenance area, however, 75.86 per cent rodent activity was reduced at tillering stage of wheat crop in neglected area. There after the rodent activity was gradualy increased. Significantly highest yield (3644 kg/ha) was also recorded in maintenance area (Fig. 6). The gradual increase in rodent activity and crop damage in wheat crop was observed throughout the season in survey area.

Thus, it is clear from the above studies that farmer's motivation through training and education for rodent management and mass control campaign under expert supervision found to have great impact on reduction in rodent population as well as crop damage.

10. Extension activities :

In addition to the research work carried out at this centre, the scientist working in this project also played a vital role in transfer of technology for rodent management to end users through training and demonstrations organized at different level which included farmers, extension officers, subject matter specialists, District Agricultural Officers and Joint Directors of Agriculture, godown managers and research personnels.

About 450 subject matter specialists/extension workers of T & V scheme, 200 godown manager/Asstt. godown managers and 8244 farmers were educated for rodent

management by training and demonstration/either through Sardar Smruti Kendra, ratri sabha, khedut charcha sabha or while visiting the rodent management laboratory. The farmer's and extension workers were also guided for "rodent management by mass control campaign" through press notes published in news papers/broadcasted by all India Radio/Telecasted by Doordrashan Kendra during December-1988, June-'89, August'89, December-'89, May-'90 and February-'92.

Mass control campaign in larger area :-

During the chronic out break of rodent in Gujarat State, Government of Gujarat declared the subsidy (50% cost of zinc phosphide or Rs. 50/ha, which ever is less) to the farmers for the purchase of rodenticide under NODP during *kharif* 1989-90. Again the pilot project was undertaken in 12 identified districts of Gujarat State during February, 1990 as per the guidelines and recommendations of the central rodent expert team. Zinc phosphide (2.4 metric tonnes) was used in first phase, will proper prebaiting after identifying the live burrows and in second phase, the newer rodenticide bromadiolone (15.8 metric tonnes) and or aluminium phosphide (2.4 metric tonnes) was used for the control of residual population of the rodents. The control campaigns were organised on mass scale under the close co-operation/involvement of all departments and farmers. It was apprised that overall 69% control was observed with the use of zinc phosphide in the first phase control and for residual control averall 84 and 80% control was observed with the use of aluminium phosphide or bromadioione, respectively. The overall control of 95% rodents was noticed in this campaign. Approximately 130 lakhs of rat were killed with the incremental cost benefit ratio (ICBR) ranging from 1:31 to 1:337 in different district which indicated overall average 1:100 ICBR. Thus, spending about 20 lakhs rupees in this project it has saved the damage worth of Rupes 20 Crores.

Similarly, Gujarat Co-operative oilseeds. Growers Federation (GROFED) also pravided zinc phosphide at 50% subsidy in groundnut to the formers who are the members of (GROFED).

Dr. Y.S.P. University of Hort. and Forestry, Solan

The Solan centre was sanctioned by ICAR during VII Five Year Plan, but the research work could be initiated during 1987 under the Dept. of Entomology of the University. The objectives of the centre and the salient findings are detailed below.

objectives :

1. Study of species composition and population ecology of rodents in Himachal Pradesh.
2. Evaluation of rodenticides in laboratory and fields.
3. Assessment of lossess caused by rodents to various horticultural crops.
4. Reproduction biology of major rodent pests of the region.
5. Evolving rodent management techniques for horticultural crops.
6. Social engineering activity on rodent control.

1. Rodent surveys

Parts of Solan, Shimla, Sirmour, Kangra and Mandi districts of Himachal Pradesh covering foot hills, mid hills and high hills have been surveyed so far since 1987, when a centre of AICRP on Rodent control was established at Solan. Rodents which inhabit these areas belong to three families viz., Sciuridae, Muridae and Hystricidae. On the basis of their habitat, they can be broadly categorised as :

1.1 *Commensal species* : These inhabit both the residential areas (houses, godowns, stores) as well as fields (orchards and crop fields), and include *Rattus rattus* and *Mus musculus* (family Muridae). The five stripped squirrel, *Funambulus pannanti* (family Sciuridae), can also be regarded as commensal species and it inhabits orchards, parks, etc. in the foot hills and valleys. *R. rattus* was also collected from the nests of birds in the forest areas near human inhabitations.

1.2 *Field species :* These inhabit only the fields (orchards, crop fields, tea plantation, forests, grasslands, etc.) and include *Bandicota bengalensis, R. meltada, M. booduga, M. platythrix*, and *Golunda ellioti* (Family Muridae).

1.3 *Wild species* : They normally inhabit forest or thick plantations and visit field occasionally. This category is represented in Himachal by *Hystrix indica* (Family Hystricidae). Apart from these, some nests probably belonging to *Vendeleuria* sp. have also been recorded. However, this species escaped trap line.

2. Population Composition

B. bengalensis and *M. musculus* were the major rodent species in orchard. The former accounted for 20.36 to 43.75, 22.64 to 29.11 and 20.55 to 36.54 per cent of total rodent population in apple, peach and pecan orchards, respectively in different years. *M. musculus*, on the other hand, accounted for 25.0 to 35.69, 26.41 to 39.63 and 23.11 to 28.84 per cent of population, respectively in the three orchard categories. *R. rattus* and *M. booduga* were also fairly distributed in the orchards.

B. bengalensis, *M. musculus* and *M. meltada* were the major pest species in vegetable crops; their per cent population being 20.26, 23.34 to 27.04 and 13.5 to 17.15, respectively in cauliflower, 28.62 to 33.36, 14.25 to 28.57 and 14.25 to 14.29, respectively in pea and 22.99 to 29.98, 19.94 to 21.86 and 10.04 to 19.71, respectively in tomato. Rodents did not appear to be a problem in cabbage. Though these were trapped from cabbage fields, yet their trapping was sporadic and no live burrow of any rodent species were recorded from these fields.

3. Rodent Damage

Damage by rodents were observed in fruit orchards and nurseries as well as in vegetable crops (pea, cauliflowers and tomato) and wheat. Cabbage was not damaged by rats and mice. Even in mixed crop fields (having cauliflower and cabbage), cabbage was not attacked. However, porcupine damage to cabbage was recorded in one fields in Solan district.

3.1 *Damage to pecan* : *B. bengalensis*, *M. meltada*, *R. rattus*, *G. ellioti*, *M. musculus*, *M. booduga* and *M. platyhrix* were recorded from pecan orchards. However, they showed specific territorial behaviour in as much as *B. bengalensis* had around 41.82 burrows on bunds and 58.18% burrows in the fields. Of the burrows inside the fields about 65.28% burrows were located within a radius of 1.5 m around pecan trees while rest were more or less evenly distributed in the orchard away from trees. The live burrows of mice were located mostly on the bunds (about 61.24%) while the rest were in the peripheral zone of the subplots. The burrows of other rats were also present mostly on the bunds (70.24%) and the rest (29.76%) were in the fields. The rodents damaged only the root system of the pecan trees and no damage to bark or fruits was recorded. *B. bengalensis* burrowed at the base of the pecan and attacked the plants from underground by gnawing and cutting the fine branches of roots as well as by girdling and completely destroying the main tap root. The trees as a result deteriorated and finally fell dead. It was observed that trees which had a burrow system within a radius of 1.5 m were prone to fatal damage, *B. bengalensis* was thus primarily responsible for damage to pecan trees. The per cent damage in unattended (no control operation) orchard was 17.42 in terms of plants killed. It was also recorded that the trees which were 20 years plus of age, could withstand the damage due to their large size and more elaborated root system.

3.2 *Apple* : *B. bengalensis* and *M. musculus* were the major rodent inhabitants of apple orchards. The nurseries of apple showed a varying rodent damage from 4.6 to 27.5% to the young plants (upto 2 years old), damage being more pronounced and severe in the nurseries which were located adjacent or near to some fallow land. The damage to root stock was also likewise high (upto 32.6%) in the plots near fallow land. The rats damaged nursery by cutting the roots of the plants not only during their burrowing activity but also because roots formed a part of their food especially during winter months, a period of scarcity of food.

3.3 *Peach* : *B bengalensis* and *M. musculus* were the most prevalent species in peach orchards. They damage trees by gnawing at the bark of the trees and also by cutting fine roots during their burrowing activity.

3.4 *Wheat*: The rodents damage to standing wheat varied from 6.32% to 8.15% in Himachal Pradesh. The damage started in 70 days old crop and increased till maturity and harvesting. The tillers were cut about 7-14 cm above ground level and felled. The grains were either consumed at the site of damage or the tillers were dragged to the burrow for either storage or consumption of grain. Damage was more pronounced around the surface opening of the burrows. The burrows of *B. bengalensis*, *R. meltada* and mice were recorded. Hoarded wheat was recorded from the burrows of *B. bengalensis* and *R. meltada*. Mice burrows had no hoarded material.

3.5 *Cauliflower* : Damage to cauliflower (head crop) varied from 6.54% to 10% in various fields, areas and seasons, whereas seed crop of cauliflower was damaged by 8.36% to 13.23%. The damage was discernible at the time of head formation. The rats cut and consumed the outer whorls and then consumed inflourescence (head). The damaged heads were unfit for human consumption. Invariably, the rats burrowed at the base of the plant. The rodent population and damage again increased at the time of seed setting in seed crop.

3.6 *Pea* : The damage to pea pods varied from 1.75 to 5.56% in different seasons and locations. The rats gnawed at and consumed pea pods. Some pea pods were recovered from the burrows also.

4. Rodent Control

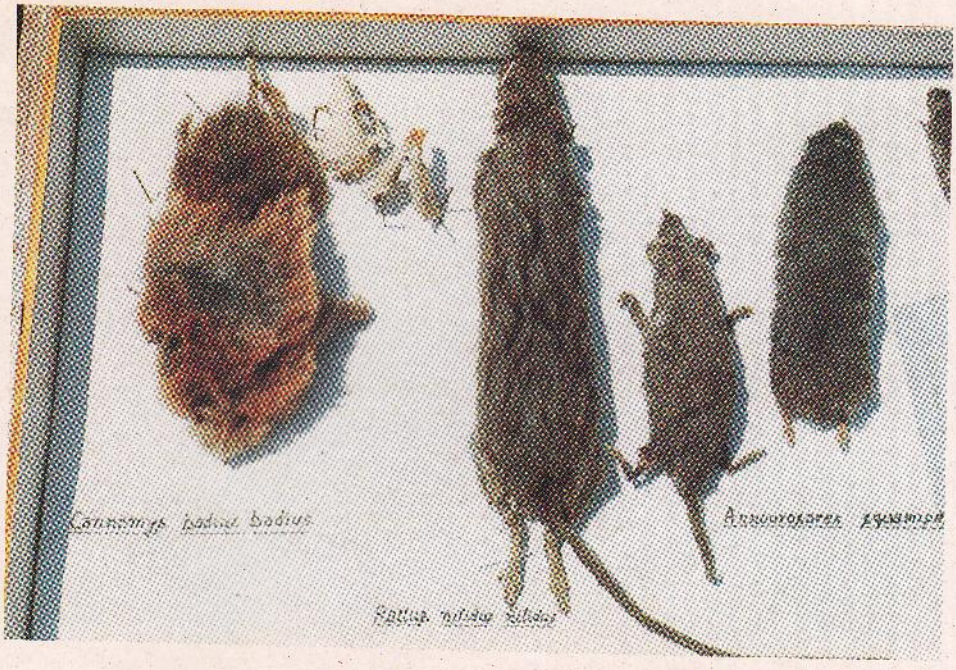
4.1 *Habitat manipulation* : Removal of shrubs and grasses under cover in the orchards results in 25% reduction in the live burrows of the rodents. It also reduced damage to the trees in the areas.

4.2 *Trapping* : Trapping proved to be an efficient method for reducing rodent activity in vegetable crops. Three days trapping every month for one year reduced trap indices of various field as well as commensal rodent species.

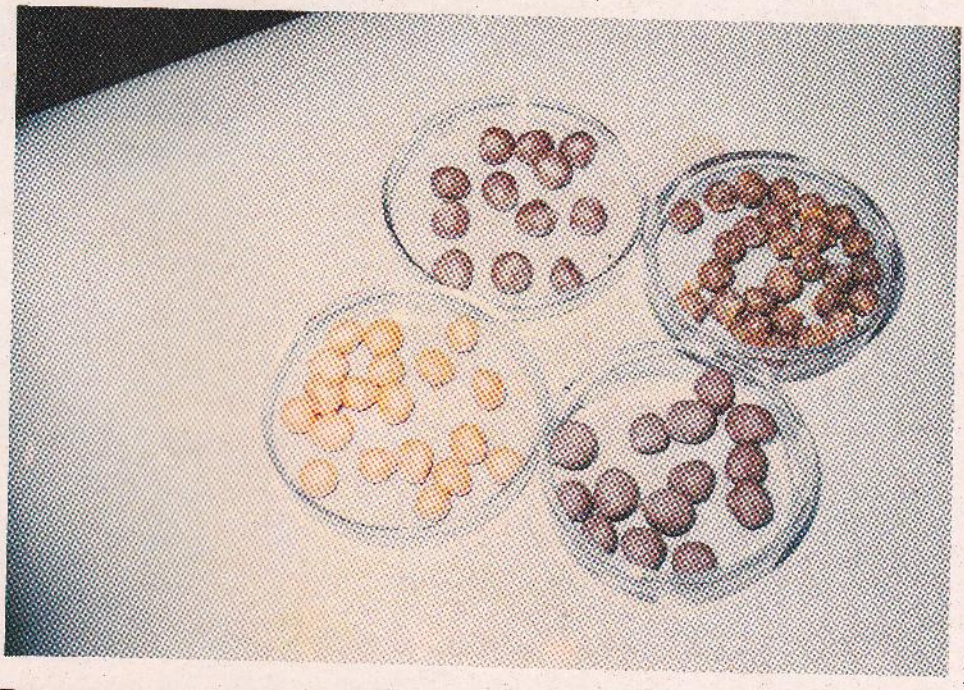
Live burrow count of *B. bengalensis*, other rats and mice were reduced maximally by 90.3, 90.3 and 85.5% respectively and minimally by 62.5, 57.14 and 40.4%

1. Typical Pineapple damage by *Rattus nitidus* in NEH region

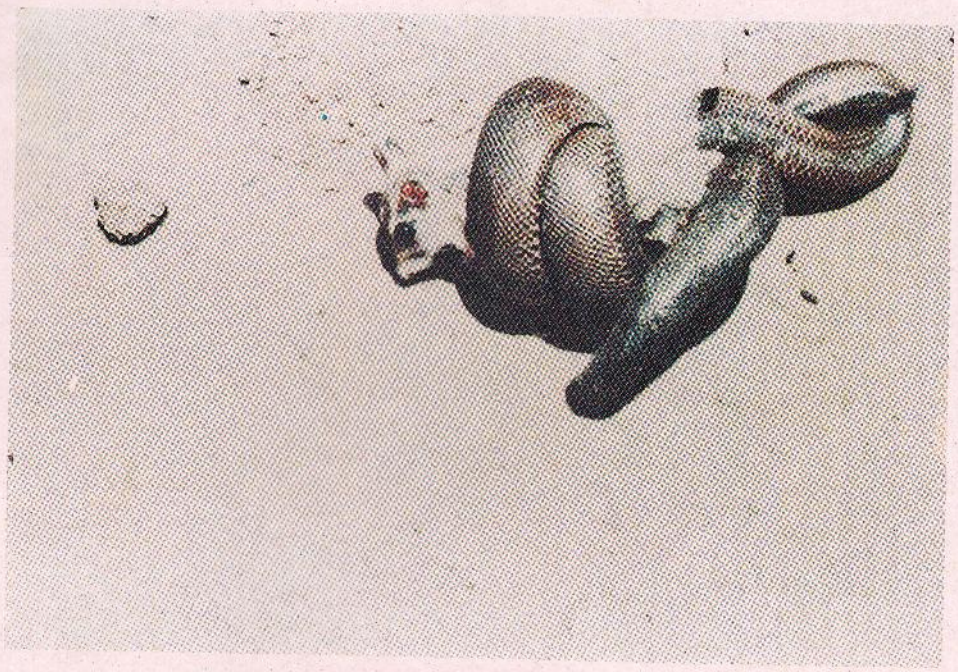
2. *Rattus rattus Wrioughtonii* feeding on coconut



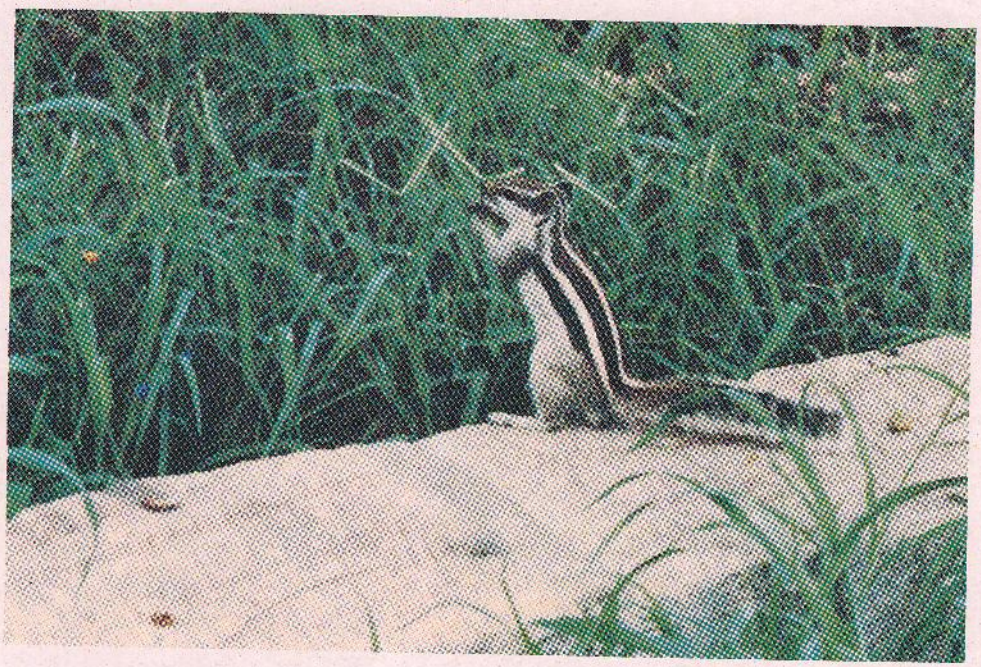
3. Some rodents of North Eastern Hill region



4. Evaluation of encapsulating methods of zinc phosphide baits for NEH Region



5. Snakes bio-control agents for rodents



6. The five striped squirrel, *Funambulus Pennanti* a major pest of horticultural crops in the plains

7. Rice demaged by rodents is easely recognisable at ripening stage

8. Typical bandicoot damage in sugar cano crop

respectively in different years, Live traps (wooden box traps with spring loaded door and wonder traps) were employed and the rodents trapped were subsequently killed by drowning.

4.6. *Rodenticides* : Aluminimum phosphide, zinc phosphide, bromadiolone, flocoumafen and cholecalciferol were employed in the fields either through surface baiting or burrow baiting as singly as well as in pulse treatments. Surface baiting proved to be rather ineffective. Burrow baiting yielded better results and pulse treatment was able to contain rodent population at lowest.

Fumigation with aluminium phosphide resulted in around 52% success whereas 2.5% zinc phosphide burrow baiting resulted in upto 75% success (generally around 50%). Cholecalciferol (0.075%) baits resulted upto 50% success. Flocoumafen and bromadiolone proved much more effective producing more than 75% success. Pulse treatment involving zinc phosphide followed by bromadiolone or flocoumafen resulted in more than 80% success. Even pulse treatment through two applications of zinc phosphide spaced at 45 days resulted in more than 75% success.

BUDGETARY STATEMENT OF AICRP ON RODENT CONTROL.

Annexure I
(Rs. in lakhs) PLAN

S. No.	Head	1978-79 & 1979-80	VI Plan 1980-85	VII Plan 1985-90	1990-91	1991-92	VIII Plan (1992-97)		
							Ongoing programme	Strengthening of ongoing & new programme	Total 8+9
1	2	3	4	5	6	7	8	9	
A	Recurring		15.80	39.84			109.00	15.00**	124.00
	Pay & Allowances	15.05	0.56	1.92	20.30	23.00	5.30	0.60 + 2.00*	7.90*
	T.A.				0.80	0.85			
	Contingency	1.61	3.89	9.96	2.00	2.20	12.90	2.40 + 3.96*	19.26*
B.	Non-Recurring								
	1. Equipment	1.80	3.23	1.76			6.40	0.10 + 4.00*	10.00*
	2. Works		1.40	2.55			16.00	—	16.50
	3. Vehicle	1.35	—	2.59			7.10	2.00	9.10
	4. Livestock	—	—	—			—	—	—
	5. Others	—	—	—			—	—	—
Total		19.81	23.96	57.62	23.10	26.05	156.70	30.06	186.76

Annexure II

STAFF SANCTIONED

ICAR INSTITUTE

Name of the Centre	Posts sanctioned										
	S3	S2	S1	Res. Assoc.	Res. Fellow	Tech. Officer (T-5)	Tech./ Lab' Asstt.	Jr. Steno	Jr. Clerk	Driver	Lab. Attdt.
CAZRI, Jodhpur	1	2	2	2	—	—	3	2	1	—	3
CPCRI, Kasaragod	—	1	2	—	—	1*	1 (T3)	—	—	—	2
NEH Region, Shillong	—	1	2	—	—	—	2	—	1	—	—
IISR, Lucknow	—	2	—	—	3	—	3	1	—	1	—

* Transferred to the Projects but not provided in the budget.

STATE AGRICULTURAL UNIVERSITIES

Name of the Centre	Posts santioned								
	Prof./ Sr. Zool.	Assoc. Prof./	Asstt. Prof./ Asstt. Zool.	Res. Asstt.	Tech. Asstt.	Lab./ Field Asstt.	Driver	Lab. Asstt.	Jr. Steno
PAU, Ludhiana	—	1	3	—	—	3	1	—	1
USA, Bangalore	1	1	—	2	—	3	1	—	1
JNKVV, Jabalpur	—	1	2	—	3	3	1	2	1
APAU. (Hyderabad), Maruteru	1	—	1	1	2	—	—	1	—
USPUH & F, Solan	—	1	1	—	3	2	1	—	—
GAU, Junagarh	—	1	1	—	1	1	1	1	—
JNKVV at Indore*	—	1	1	—	1	2	—	—	—
HAU, Hisar*	—	1	1	—	2	—	1	1	1

* Sanctioned during VIII Five Year Plan.

Annnxure III

STAFF POSITION OF DIFFERENT CENTRES

S. No.	Name & Designation	Date of joining the project	Date of leaving
1.	Central Arid Zone Research Institute, Jodhpur.		
	a) Projecr Coordinating Unit :		
1.	Dr. A.P. Jain, Project Coordinator	Jan. '85	Jan. '90
2.	Dr. P.K. Ghosh, Project Coordinator	Feb. '90	May. 1992
3.	Dr. B.D. Rana, Project Coordinator	June '92	Contd.
4.	Mr. T.S. Bhati, Jr. Stenographer	March '85	July, '89
5.	Mr. Kan Singh. Jr. Stenographer	Aug. '89	May, 1992
6.	Miss Kamla, Jr. Clerk	—	July '89
	b) Cooperating Centre :		
1.	Mr. B.K. Soni, Scientist (Sr. Scale)	Aug. '88	Contd.
2.	Dr. R.S. Tripathi, Scientist (Sr. Scale)	July '85	Contd.
3.	Mrs. N. Patel, Scientist	Aug. '86	Contd.
4.	Mr. H.P. Sharma	Jan. '82	Contd.
5.	Dr. (Mrs.) F. Parveen, Research Associate	March '85	Contd.
6.	Mrs. Manju Mathur Research Associate	Jan. '92	Contd.
7.	Dr. M. Idris, Technical Assistant	Sept. '87	Contd.
8.	Mr. D.K. Saini, Technical Assistant	—	Transferred in 1990
9.	Mr. Dev Raj, Lab. Attendant	—	Contd.
10.	Mr. Bhanwar Lal, Lab. Attendant	—	Transferred in 1990
2.	Punjab Agricultural University, Ludhiana		
1.	Dr. V.R. Parshad, Zoologist (Rodents), Assoc. Professor	7.8.82	Contd.
2.	Dr. C.S. Malhi, Asstt. Zoologist or Asstt. Professor	16.4.86	Contd.
3.	Dr. N. Ahmad. Asstt. Zoologist or Asstt. Professor	24.1.88	Contd.
4.	Dr. M.S. Saini, Asstt. Zoologist or Asstt. Professor	24.1.88	Contd.
5.	Mrs. Inderjit Kaur, Jr. Stenographer	11.5.90	Contd.
6.	Mr. A. Sagar, Agril, Sub-Inspector	30.6.89	Contd.
7.	Mr. Nasib Singh, Agril. Sub-Inspector	1.4.86	Contd.
8.	Mr. S. Singh, Agril. Sub-Inspector	1.6.80	Contd.
9.	Mr. Prem Singh, Driver	9.6.81	Contd.
3.	University of Agricultultural Sciences, Bangalore		
1.	Dr. K. Srihari, Sr. Zoologist	1.1.78	Contd.
2.	Dr. (Mrs.) S. Sridhara, Zoologist	1.1.78	Contd.

3.	Dr. B.K. Guruprasad Research Assistant	28.2.79	Contd.
4.	Dr. G. Govindraj, Research Assistant		
5.	B. Satya Vathi, Jr. Stenographer	26.2.81	Contd.
6.	Mr. A. Ravishankar, Fieid Assistant	19.8.81	Contd.
7.	Mr. A.C. Shivaji, Field Assistant	19.8.81	Contd.
8.	Mr. B.N. Shivaji, Field Assistant	19.8.81	Contd.
9.	Mr. Gangeramaiah, Lab. Attendant	14.11.85	Contd.
10.	Mr. Rajana, Lab. Attendant	24.7.87	Contd.
11.	Mr. Krishnappa. Driver	27.10.81	Contd.
4.	Central Plantation Crops Research Institute, Kasaragod		
1.	Dr. S.K. Bhat, Tech. Officer (T-6) (Transferred to the Project)	April, 84	Contd.
2.	Mrs. A. Sujatha, Tech. Officer (T-5) (Transferred to the Projeci)	Sept. :84	Contd.
3.	Mr, Basavarajiah Tech Asstt. (T-II3)	June, 82	April, 87
4.	Mr. Anada Gowadia, Lab. Attdt.	April, 87	Contd.
5.	ICAR Research Complex for NEH Region, Shillong		
1.	Dr. Y.P. Singh, Scientist Ssl	—	—
2,	Dr. D. Kumar, Research Associate	7.5.85	Contd.
3.	Mr. B.B. Kushwaha, Research Associate	—	Contd,
4.	Mr. C.S. Prasad, Research Assistant	7.5.85	8.7.85
5.	Mr. O.N. Tiwari, Lab Assistant	7.5.84	Contd.
6.	Mr. M.C. Das, Lab Asstt.	8.12.83	Contd.
7.	Mrs. N. Paswett, Jr. Stenographer	1.12.84	Contd.
6.	Indian Institute of Sugarcane Research, Lucknow		
1.	Dr. D.C. Srivastava, Scientist S-2	—	Contd.
2.	Mr. M.P. Sharma, Research/Lab. Asstt. (T-1)	—	Contd.
3.	Mr. I.P. Maurya Research/Lab. Asstt.	—	Contd.
4.	Mr. O.S. Joshiya, Research/Lab. Asstt. (T-I)	—	Condt.
5.	Mr. R.K. Prasad, Driver	—	Contd.
7.	J.N. Krishi Vishwavidyalaya, Jabalpur		
1.	Dr. R.K. Patel, Associate Professor	27.4.87	Contd.
2.	Dr. R. Pachori, Asstt. Professor	10.1.85	1.2.89
3.	Dr. O.P. Dubey, Asstt. Professor	1.2.89	Contd.
4.	Mr. A.K. Awasthi, Technical Assistant	28.3.88	Contd.
5.	Smt. Asha Dubey, Jr. Steno Typist	3.3.87	4.4.89
6.	Ku. Vimla Koshti, Jr. Steno Typist	1.4.89	Contd.

7.	Mr. B.L. Kewat, Field Asstt.	7.7.83	Contd.
8.	Mr. V.R. Fulzale, Field Asstt.	3.8.83	14.6.88
9.	Mr. B.P. Sharma, Field Assistant	1.2.86	6.12.88
10.	Mr. B.L. Dubey, Field Assistant	26.7.88	28.2.89
11.	Mr. R.B. Garg, Field Assistant	6.12.88	Contd.
12.	Mr. H.P. Kurmi, Field Assistant	7.7.83	Contd.
13.	Mr. P.L. Yadav, Driver	7.7.83	Contd.
8.	A.P. Agricultural University, Hyderabad (Stationed at A.R.S., Maruteru)		
1.	Dr. A. Ranga Reddy, Sr. Zoologist	30.8.86	Contd.
2.	K. Chander Paul, Sub. Assistant	23.6.86	Contd.
3.	Suv. Subbaiah, Sub. Asstt.	1.10.89	Contd.
9.	Gujarat Agril. University, Junagadh		
1.	Mr. H J. Vyas, Assoc. Prof.	7.12.87	Contd.
2.	Mr. V.R. Virani, Asstt. Prof.	8.2.88	31.7 88
3.	Mr. V.S. Kotadia, Asstt. Prof.	1.8.88	Contd.
4.	Mr. V.R. Virani, Tech. Asstt.	11.11.87	7.2.88
5.	Mr. T. Garge, Tech. Asstt.	6.2.88	31.7.88
6.	Mr. V.R. Virani, Tech. Asstt.	1.8.88	Contd.
7.	Mr. B.K. Patel, Field Asstt.	14.8.89	26 9.89
8.	Mr. A M. Sulemani, Lab. Attdt.	15.2.88	31.7.88
9.	Mr. K.B. Parmar, Lab. Attdt.	31.1.90	31.7.92
10.	Mr. H.H. Girnani, Lab. Attdt.	1.3.93	Contd.
11.	Mr. S.B. Virgana, Driver	1.4.88	Contd.
10.	Dr. Y.S.P. University of Hort. & Forestry, Solan		
1.	Dr. Chander Sheikher, Assoc. Professor	—	Contd.
2.	Dr. S.D. Jain, Asst. Professor	—	Contd.
3.	Tech. Assistant (I)	Filled	
4.	Lab. Assistant (I)	Filled	
5.	Field Assistant (I)	Filled	
6.	Driver (I)	Filled	

Staff sanctioned for New Centres to be opened in VIII Plan

11.	JNKVV, Indore	
1.	Assoc. Professor	— One
2.	Asstt. Professor	— One
3.	Tech. Assistant	— One
4.	Field/Lab. Attdt.	— Two

12. Haryana Agril. University, Hisar

1.	Associate Professor	— One
2.	Asstt. Professor	— One
3.	Tech. Assistant	— Two
4.	Laboratory Attdt.	— One
5.	Jr. Steno	— One
6.	Driver	— One

13. Project Coordinator's Cell (CAZRI)

1.	Senior Scientist	— One
2.	Sr. Technical Officer (T 6)	— Two
3.	Driver	— One
4.	Lab. Atıdt.	— One

ANNEXURE IV

RECOMMENDATIONS OF FIRST QRT (For the period 1977-1984)

S. No.	Recommendations	Comments of ICAR	Action taken
1	2	3	4
1.	The project needs strengthening with respect to its staff as many posts of S-1 are lying vacant for want of recognitions of Zoology as a discipline for competitive examination of A.R.S. in the ICAR based cooperating centres including the Coordinating Unit.	If approved, the ASRB may be requested to include Zoology as a discipline for ARS competitive examinations.	It is still under consideration of ICAR.
2.	The project leader should invariably be a Senior Scientist at least a S-3 Scientist for each Centre and accordingly the post of Project Coordinator may be upgraded to at least S-4 or above.	It is a good recommendation and should be acceptable.	In the university based centres Associate Professor is heading the centres, whereas, in ICAR Institute based centres the incharge of the project is a S-3 Scientist. However, ICAR is considering to upgrade the post
3.	The posts of Research Fellows and Research Associates may be regularised for smooth running of the project	As stated (2) above.	This has been implemented in the university based cent-

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	as the persons engaged against these posts normally go away and the work of project is disrupted.		res whose E.F.C. Memo and budget is submitted through project coordinator but it is still to be implimented in ICAR Institute based centres where project coordinator has no control on budget etc.
4.	Looking to the magnitude of field work involved in conducting research programmes particularly with large number of traps, cages poison bait stations and visit to farmers fields, a Jeep may invariably be provided to each centre whether it is Agricultural University based or ICAR Institute based centres.	The suggestion will be consider on the merits and the need of mobility of work involved in fieid programme subject to approval of Finance/Planning Commission.	Except for Kasaragod Centre, a vehicle has been provided to each centre.
5.	Social engineering activities on rodent coent control must be intensified as it has proved beneficial to the farmers. Larger area be undertaken under this projeet so that large numbers of farming community are benefited. A close	Acceptable as proposed.	This has been imple mented. After every 2-3 years, villages adopted for social engineering activity project, have been

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	liaison with other developing agencies be identified to popularise rodent control technology at the door step of farmers. The social engineering activity area may changed after two or three years to help larger number of farmers.		duly changed at all the centres where project is in operation.
6.	Work on migration of rodents activity patterns & ethology under field conditions be worked out and equipment like telemetry and closed circuit T.V. etc. be procured for such studies.	Council accepts the suggestion subject to availability of funds.	This has been partly achieved as only Ludhiana centre could get this facility. This will be considered for other advanced centres with 8th plan period.
7.	The three established centres i.e. CAZRI, Jodhpur, PAU, Ludhiana and UAS, Bangalore may undertake prepartion of Video films on social engineering activity on rodent control which may be shown to farmers even though Doordarshan Kendras. For UAS, Bangalore Centre, a provision of an animal House is a must.	It is good recommendation and should be acceptable.	UAS, Bangalore and CAZRI centres have prepared video films. Bangalare centre has got the animal house.
8.	The Committee is of the opinion that a National Centre of Rodents	The proposal will be examined and the appointment of	This is under consider- of ICAR.

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	Research may be established possibly at the CAZRI, Jodhpur where rodent research is being conducted since 1960 and Prof. of Eminence scheme is also awarded on Rodents to CAZRI. Besides, basic infrastructure and other building facilities are sufficiently developed here. However, sub-committee may be appointed by ICAR to examine this proposal.	a sub-committee will be considered by the ICAR.	
9.	CPCRI, Kasaragod centre of the project need be shifted to Vittal as better facilities for field and laboratory work exist here. This centre would need staff strengthening at top priority, at least a S-3 scientist should head the project independently.	The proposal is aggreable and the modifications suggested will be considered subject to approval of Finance/Planning Commission.	It was tried to get the vacant posts filled before the proposed shifting is made. Director CPCRI informed that he proposals for filling these posts are lying ICAR/ ASRB.
10.	Each centre should adopt few villages in their vicinity and develop them as 'Model villages' almost free of rodents.	Council accepts the recommendations,	Because of full involvement in social engineering activity on rodent control this could not be achieved. However,

1	2	3	4
			control operations and free advisory services were rendered.
11.	Rodent fauna of the country should be surveyed. All centres should invariably develop museums depicting rodent damage, major rodent pests and befitting management technology.	The sub-committee proposed at (8) above may also consider the suggestions.	This could not be attempted due to various constraints.
12.	Top priority has to be given in recruiting personnel against vacant posts in ICAR institutions to achieve the targets of the project.	Aggreable as proposed.	Attempts were made but the situation has not improved so far.
13.	The workshops should be held regularly and at different centres so that workers engaged in this field acquaint themselves with the work of other centres.	Aggreable as proposed.	It is being implemented.
14.	Periodic meetings of project leaders may be arranged to discuss annual project reports and also to discuss constraints, if any.	The sub-committee proposed at (8) may also consider the suggestion.	Because of shortage of T.A. funds allocated this could not be implemented.
15.	Contingencies, T.A. grants etc. at all the centres need be increased keeping in view of the high prices of	The contingencies has already been increased by the Council. T.A. grant should be con-	Although T.A. funds were raised but were not proportional to

1	2	3	4
	material increased labour costs and hike in tariff.	sidered favourably.	the field work involved.
16.	Restricted foreign visits may be approved to help the workers in India keep abreast with the advancement in this field abroad.	Aggreable as proposed.	This could not be initiated.
17.	The QRT is of the firm opinion that matching funds are not provided for the smooth running of the project looking to the magnitude of problems rodents pose. Particularly in the field of dry land agriculture, in developing forest zone, improve economy of rural masses in general and of hill people in particular. If the country is able to reduce rodent lossses from 10-15% to even half India alone can feed 25 other Nations of the world. However, other areas like legumes and oilseeds production would get a boost in production provided. This project gets its due share in spreading its net work without any constraints whatsoever.	This aspect has already taken account while considering the VII Plan.	Though increased allocation for the project was agreed upon but matching funds for non-recurring contingencies and T.A. etc. were not provided.

ANNEXURE V

RECOMMENDATIONS OF SECOND QRT (FOR THE PERIOD 1985-89).

Recommendations	*Comments of ICAR*	*Recommendations of the Sub-committee*
1. The Members of the QRT or Rodent Control, after having evaluated the research work at all the 10 Centres of the AICRP, have come to the conclusion that the status of the AICRP should be raised to that of a Directorate of Vertebrate Pest Management at Jodhpur. An AICRP or Economic ornithology is presently in operation in the ICAR system. It is strongly recommended that the Council may consider to bring the AICRP also (under the common discipline of vertebrate pest Management) within the framework of the proposed Directorate of vertebrate Pest Management which should include : a) Rodent Pest Management. b) Bird pest Management.	The recommendation for upgrading the Project to Directorate of Vertebrate Pest Management at CAZRI, Jodhpur is noted.	The QRT has made a recommendation to upgrade the cordinated Project into a project directorate. The Sub-Committee thereafter examining the contributions of the project decided to recommend to the Council to continue the statusquo for the present.

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	c) Management of other mammals, like fruit bats, monkeys, elephants and ungulates.		
2.	The QRT members have discussed the future thrust areas of research at various AICRP centres, and strongly recommend that the three older centres of AICRP at Jodhpur, Ludhiana and Bangalore should be raised to the status of "Centres of Excellence". These centres should conduct indepth, long term studies, such as chaemo-communication, ecological succession and taxonomy (at Jodhpur), studies in toxicological, behavioural ecology and prey - predator (at Ludhiana), and behavioural ecology in rainfed agriculture, mitigation of poison shyness using neuro-chemicals and hormones (at Bangalore).	The recommendation has merit. The suggestions made by QRT will be kept in our future planning of programmes and activities of the project.	The three centres at Bangalore, Ludhiana and Jodhpur have contributed very much in the management of rodents in the project. They may be identified as "Lead Centres" instead of" Centres of Excellence" and may concentrate on the programmes of *research identified by the QRT.*

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	For taking up fundamental studies as suggested above these three centres should be strengthened by providing more scientists and technical Staff, equipments, T.A., and contingency (vide Annexure iv).		
3.	It is essential to establish a strong Coordinating cell of the AICRP or Rodent Control under the charge of the Project Coordinator at CAZRI with additional staff and funds mentioned in Annexure - IV. The staff will assist in maintaining a Central Data Bank of information on rodent pest management, and in extension activities.	Need-based strengthening of P.C. Cell has been proposed in the VIII plan. Computer facilities are also proposed to be provided.	3 & 4 The progress of the project suffers very much in the absence of a regular project coordinator. The Sub-Committee strongly recommends to the Council to recruit a *regular project coordinator early.*
4.	The post of Project Coordinator should be filled up by a specialist in rodent research. He should not be deprived of conducting research in his field of specialization. As such, the AICRP centre, where the Project Coordinator	Action has been initiated to fill the post of Project Coordinator. As per the ICAR policy, the Project Coordinators have been permitted to undertake limited research recommendation of attaching AICRP centre to P.C. when both are located at the same place	

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	is located, should be attached to the project coordinator.	will be examined.	
5.	The Coordinating centre should have facilities taxonomic studies to identify rodents upto subspecific and specific level. It should also develop a good museum displyaing economically important rodent species found in India. Hence, it is necessary that the Coordinating centres should be strengthened accordingly (vide Annexure V)	The recommendation is noted. To begin with efforts will be made to provide this facility in the main centre at Central Arid Zone Research Institute, Jodhpur.	
6.	In depth investigations of the mode of action of rodenticides on various species of rodents should be taken up at Jodhpur, Bangalore and Ludhiana centres by creasing a position of a Biochemist / Pharmacologist at each centre. Additionally, there is a need to screen certain plant products which have rodenticidal properties. This work should	The recommendation is acceptable as proposed. The Project Coordinotor will be requested to forward a consolidated proposal on this aspect.	

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	also be taken up by the Biochemist/Pharmacologist.		
7.	Various coordinating centres of this Project are located to boost production in the major cropped area in the Country. But considering the intensive and fast changing cropping pattern, it is recommended that some more centres and field stations should be set up as detailed below :- a) In recent years, large scale plantation of oil-palm has been established in Andaman & Nicobar Islands. A serious magnitude of losses to oil-palm inflicted by rodents has been noticed there. It has also been reported that the rodents there do not feed on zinc phosphide baits and even on anticoagulant wax preparations. These problems	The possibility of opening additional centres in the VIII plan is under consideration.	Oil palm has been introduced in a big way in our country in some of the states. The rodent problem on oil palm is very serious. Hence, the Sub-committee recommends initiating some research on rodent management in oil palm through the project. *New centres may be established in Shimoga in Karnataka state.* As regards other new centres, the Sub-committees suggested, it may be taken up in a phased manner.

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	have to be studied in greater depth so that a well proven rodent management practice is available to the actual grower. Therefore, a centre of this AICRP to set up in the Andaman & Nicobar Islands with the staff suggested in Annexure IV.		
	b) In order to enlarge the scope of the project to include the management of rodent pests in vegetable crop fields-an area of considerable economic importance it is recommended that a new co-operating centre of the project be set up in the Department of Zoology, Haryana Agricultural University, Hisar, with the staff suggested in Annexure 4.		

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	c) There is a need-felt scope of opening four more field stations at Palampur (Himachal Pradesh) to cover the wheat cultivation, at Indore (Madhya Pradesh) for soybean at Aizwal (Mizoram) for bamboo, and at Kota (Rajasthan) to cover irrigated intensive cultivation belt of south-eastern Rajasthan, with the supporting staff suggested in Annexure 4.		
8.	All the Cooperating centres of the AICRP must be provided with a rodent house and rattery if the facility has already not been created for undertaking experimental work.	A number of centres already have a rodent house and rattery which were constructed during the VI & VII plan periods. Centres which do not have this facility will be provided this in the VIII Plan.	
9.	With a view to disseminate the proven technology on rodent pest management more effectively, the Council should	The possibility of establishing Operational Research Projects on Rodent Pest Management in various Institutes/Agricultural Uni-	

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	establish ORP specifically on Rodent Pest Management at appropriate centres in various ICAR Institutes and State Agricultural Universities. Additionally Summer Institutes should be organised to train the scientists in progressive research/technology.	versities will be explored in consultation with the Extension Division.	
10.	To enhance the coordination, cooperation and collaboration amongst the rodent research Scientists, ICAR should periodically organise national symposium on recent developments on Rodent Pest Management, at an interval of 3 years.	The Council has already agreed to the proposal to hold a National Symposium on Rodent Pest Management at CAZRI, Jodhpur.	
11.	The National Programme for Rodent Pest Management, launched by AICRP in collaboration with the Plant Protection Directorate, should be revived and given impetus by the Council.	Acceptable as proposed. The Directorate of Plant protection will be requested to revive the National Programme for rodent Pest Management.	
12.	The Annual Progress Reports and other related published	This is the responsibility of the Project Coordinator & he has been	

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	work should be exchanged among the different centres. This will keep the scientists in touch with the trends of research under the project.	asked to take necessary action.	
13.	Methodology for evaluating qualitative and quantitative crop losses or natural pest population, based on sufficient statistical unit samples, should be followed uniformly by all the centres vide Rodent Newsletter. Vol. 5(2).	Suggestion is accepted. The Project Coordinator has been asked to take necessary action in this respect.	
14.	The AICRP on Rodent control has carried out intensive work on chemical control. Simultaneously now, centres should initiate work on the role of predators (like mongoose, reptiles, snakes and lizards) which regulate the population or rodent pests in nature.	The recommendation is acceptable. Keeping in view the role of predators in rodent, management, facilities for these studies will be provided at two or three centres.	
15.	The basic objective in rodent pest management should be to develop a complete package of practices/techniques crop-	The Project Coordinator has been requested to bring out the Technology Bulletin on Rodent Pest Management giving all the details	

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	wise and in succession of crop phenology from presowing till harvesting or storage in residential houses.	as recommended by the QRT.	
16.	The use of indigenous devices such as the use of traditional rat-traps, and smoking of burrows utilising paddy husk are prevalent in west Godavari district of Andhra Pradesh. These practices should be encouraged on large scale. These methods have been professionalised in that area and have generated self-employment for landless labourers.	This is an excellent suggestion. The Project Coordinator has been informed to initiate further action in this respect.	
17.	As an effective media for training of rural community for organising regular large area campaigns, video-films demonstrating the action plans on rodent pest management need to be developed, highlighting the seriousness, of the rodent problems. To achieve this objectives, each centre should be equipped with a T. V.,	The recommendation is noted.	

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	V. C. R., V. C. P. and other accessories as essential items besides other audio - visual aids.		
18.	The public, by and large, remains apathetic and unconcerned about rodent control. Special short duration trainings should be organised to utilise the spare time and labour of the rural community. The rural women, school going children and teachers should be actively involved in these trainings.	The recommendation is acceptable as proposed. Social engineerins is an important component of the Project.	
	ADMINISTRATIVE		
19.	In, certain, centres, scientist are experiencing difficulty in operating the project since the allocated resources are pooled those of the Institute/Department and sufficient support was not forthcoming, This is particularly evident in relation to mobility, and placement of scientists and support-	It is a good recommendation and will be kept in view while finalising the VIII plan proposals,	

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	ing technical staff. This aspect has to be immediately streamlined for efficient functioning of the project and appropriate utilisation of the alloted resources. In centres under ICAR Institutes, funds allocated to support staff and other facilities for operating the project under Non-Plan should be fully utilised for this project.		
20.	For ensuring the mobility of the research team and to facilitate research work, all centres should be provided with a jeep and driver, and separate funds clearly earmarked for the purpose without merging them with the Institute/University budget. It is also essential that the facility should be within the administrative powers of the scientist in-charge.	All the centres have been provided with a vehicle. Problem with use of these vehicles can be sorted out administratively.	
21.	All centres should be provided with a Junior stenogra-	The matter will be looked into.	

2	3	4
phar for exclusive use of the Project.		
22. It view of large areas of field survey and demonstrations, the expenditure on account of travel should be suitably in-ereased.	The recommendation is noted.	
23. The QRT is deeply concerned about the number of post lying vacant at various centres for several years; The Council may like to take up a special recruitment drive for filling up of the Scientific positions at the Council level and other positions at the Institute University level.	The QRT's concern is noted. ASRB and universities will be approached to expedite the fill ing up of vacant posts under the project.	
24. The adhoc temporary research positions like Research Fellows Associates should be technical series (T-I-T-6) for smooth running of the project.	It is a good suggestion and it is envisaged that during VIII plan all the Research Fellows/Associaties positions while converted to technical positions.	
25. There has been no exposure of the Projeet scientists to the working of advance centres is foreign countries to wider the horizons of rodent research	The recommendation is noted. An effort will be made to give foreign exposure to the scientists when ever possible.	

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	work in the the country, it is essential to depute the scientists working in the AICRP on short term as assignments to the foreign laboratories like the Department of Rodent Research, University of California, Davis, Department of Rodent control, Danish Pest Infestation Laboratory, Lyngby, Denmark, Institute of Ecology and Evolution, Moscow etc. Accordingly, it is recommended that an amount of Rs. 5.00 lakhs may be provided during the VIII Five - Year plan for this purpose.		
26.	The team reiterates the recommendation of the previous QRT or recognising zoology as one of disciplines for the ARS examination and rodent pest management should be evolved as a distinct agricultural discipline in Agricultural Universities.	The recommennation has merit and the matter will be pursued with ASRB.	The suggestions made by the QRT to include zoology as one of the discipline for ARS examination for rodent pest management is not recommended since knowledge of agriculture will be needed in view of the damage caused by rodent number of crops. The sub-committee recommends all other recommendations made by the QRT for acceptance by the Council.