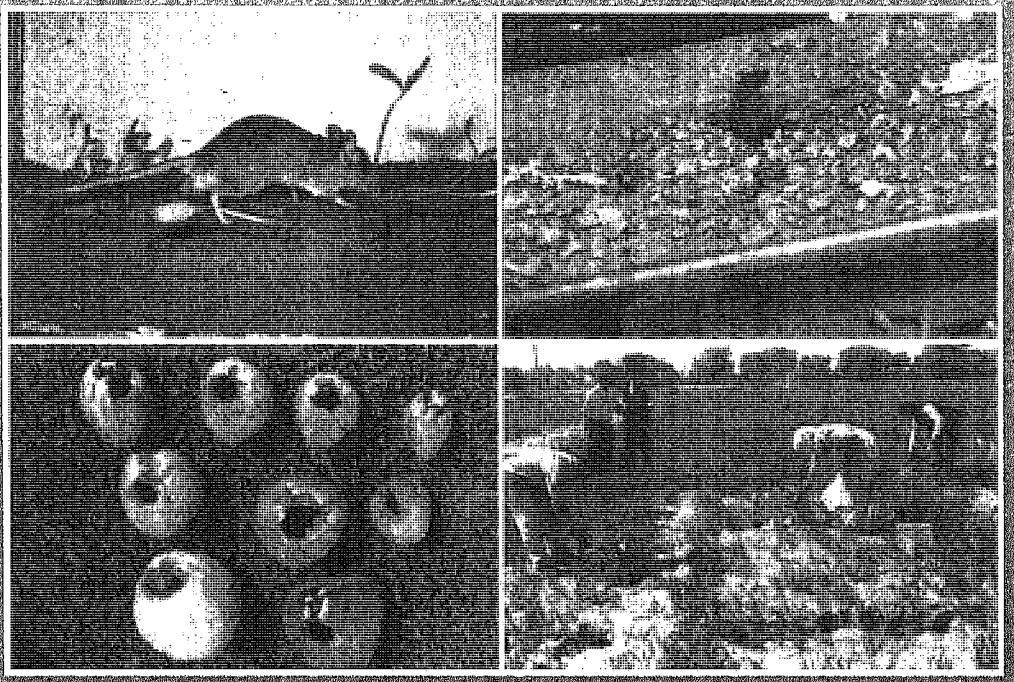
GLIMPSES OF RODENT RESEARCH IN INDIA



B.D. RANA
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AND
VIPIN CHAUDHARY

ICAR

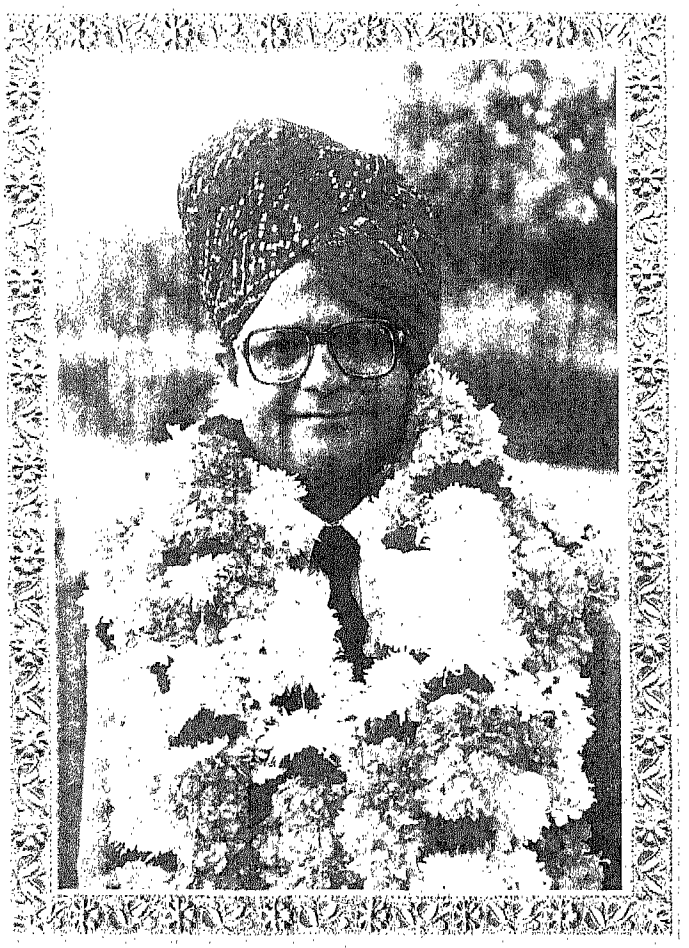
Project Co-ordinator's Cell

All India Co-ordinated Research Project on Rodent Control

Central Arid Zone Research Institute

Jodhpur - 342 003, India

IN THE MEMORY OF



Late Dr. Ishwar Prakash

(1931 - 2002)

FATHER OF RODENTOLOGY IN INDIA

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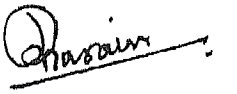
FOREWORD

I am extremely happy to learn that the XIth All India Group Meeting on Rodent Control is being organized at Central Arid Zone Research Institute, Jodhpur from November 12 to 14, 2002. While reviewing the progress of the work at various centres of the Rodent Network done so far, the AICRP has also compiled the research information generated by it on Rodent. It is indeed appreciable that this volume is dedicated to late Dr. Ishwar Prakashji, a renowned Rodentologist, who spent his professional life at CAZRI and who conducted and supervised the research work on rodent control for more than three decades. The AICRP on Rodent Control was initiated by Dr. Ishwar Prakash in 1977, and the Centre has completed 25 years of its existence and has reached newer heights. I congratulate all the contributors in this volume for providing salient findings of their Centres in a popular language. I also appreciate the gesture of AICRP on Rodent at CAZRI, in bringing out this timely publication.

I am sure that the publication will be helpful to researchers, industrial houses and farmers at large to combat the menace of rodents, especially in the arid western Rajasthan.



(PRATAP NARAIN)
DIRECTOR
Central Arid Zone Researc Institure
Jodhpur

PREFACE

Rodents are well known competitors of man since times immemorial. They destroy the crops in fields and threshing yards, devour and contaminate our stored food and other commodities and spread several dreadful diseases. Until 1950's most of work on rodents was done by medical scientists from the epidimeological point of view. Role of rodents in food production was in fact realized during early sixties, however, systematic and concerted research efforts were initiated with the establishment of AICRP on Rodent Control in 1977. Now we are completing 25 years. During all these years Project scientists have made steady progress in exploring the ecology, ethology, damaging propensities and management of rodents.

The scientists engaged in the Project have generated lot of information which have been published in the form of research papers, Technical reports and reviews in Journals of National and International repute. Periodical publication of Rodent Newsletter by us has provided a convenient medium for rodent workers round the country to disseminate new information for peer enlightenment. Besides these publications, the Project has been bringing out technology bulletins, monographs, reports, etc. for popularization of its research and extension activities. Present compilation is an attempt to collate and compile the salient achievements of the Project in a popular/semi technical language as "Glimpses of Rodent Research in India". I appreciate the efforts of all our scientists who have strived hard for rodent control research at their respective centers.

This compilation is being dedicated to late Dr. Ishwar Prakash, an architect of Rodent research in the country and is being released during forthcoming XIth Group Meeting on Rodent Control at CAZRI, Jodhpur. I am sure this publication would prove its worth amongst students, scientists, development and extension functionaries and policy planners.

I feel greatly privileged in expressing my sincere thanks to Dr. Panjab Singh, Director General, ICAR & Secretary, DARE (GOI), Dr. Mangla Rai, Dy. Director General (Crop Sciences), Dr. O.P. Dubey, Assistant Director General (PP), Indian Council of Agricultural Research, New Delhi and Dr. Pratap Narain, Director, CAZRI, Jodhpur for extending all possible help and encouragement in execution of the Project and for sincere guidance. I am also thankful to all the contributors for their quick response at our short request. Shri Harish Kumar, P.S. Yadav, Surjeet Singh, Ramesh Chand Meena and Ashok Sankhla deserve special appreciation for their efficient secretarial and technical assistance.

(B.D. Rana)
Project Coordinator
AINP on Rodent Control

Jodhpur
08.11.2002

DR. ISHWAR PRAKASH

Dr. Ishwar Prakash, Ph.D., D.Sc., FNA left for heavenly abode on 14.5.2002. He was 71. He is survived by his wife, a son and two daughters.

Dr. Ishwar Prakash, popularly known as IP among his friends and colleagues was born on 17.12.1931 at Jaipur. He was educated at Mount Abu, Pilani and Jaipur. He took his M.Sc. (Zoology) degree in 1952 from University of Rajasthan, Jaipur. He was awarded Ph.D. in Zoology from the same University in 1957 on Ecology of desert mammals under a UNESCO Project. He was conferred with D.Sc. degree on his thesis on Ecology and Management of Desert rodents in 1983 by University of Rajasthan, Jaipur.

After a brief instinct as a Lecturer in Zoology in Rajasthan Education Service (RES) and University of Rajasthan, Jaipur, Dr. Prakash joined the Central Arid Zone Research Institute, Jodhpur as Animal Ecologist in 1961. CAZRI was his real "Karm Bhoomi" where he served for over three decades in different capacities and retired on 31.12.1991. Dr. Prakash has been instrumental in initiating an ICAR funded All India Coordinated Research Project on Rodent Control in 1977 and served as its founder Project Coordinator. The Rodent Newsletter, the only Newsletter/Journal on Rodents published from India was started by him, which is still in great demand from the rodentologists world over. Based on his outstanding contributions and leadership in the field of rodent ecology, Dr. Prakash was awarded the prestigious chair of Professor of Eminence from 1980-1991. He was solely responsible for establishing the discipline of rodentology on a firm pedestal in India. After retirement also he was so active and dedicated scientist that he got selected, as Senior Scientist of Indian National Science Academy and continued as Professor Emeritus of DST funded project on small mammals of Aravallies at Desert Regional Station of Zoological Survey of India, Jodhpur.

Dr. Prakash has done pioneering research on Ecology of desert mammals, Environmental Analysis and Desertification studies. In addition to his accomplishments on rodent research, for which he was referred as "Father of Indian Rodentology", Dr. Prakash was an authority on desert fauna in general having carried out pioneering work on insectivores, primates, chiropterans and carnivores inhabiting the region. During his stay in Birla College of Science, Pilani as a M.Sc. student, he was so much fascinated by the Indian desert gerbils, Meriones hurrianae inhabiting the sandy plains that he opted this tiny rodent species as his experimental animal and continued to explore its zoogeography, ecology, breeding, feeding, pheromonal communication, burrowing and other behavioural manifestations. His love for the desert gerbils has made this species to be one of the most studied mammals of the world.

During his professional career, honours and awards continued to chase Dr. Prakash. He was the recipient of prestigious Rafi Ahmad Kidwai Award of ICAR for the biennium 1974-75 and the Harswarup Memorial Award of INSA in 1990. He has also been elected Fellow of INSA and a foreign Fellow of International Theriological Society. He had the distinction of being invited to serve on a number of National and International Committees, viz., UGC, ICAR, DST, ICMR, Planning Commission, Wildlife Institute of India, MAB Committee, Ministry of Environment, FAO/ DANIDA panel etc.

A prodigiously hard working man, Dr. Prakash has over 500 research publications to his credit. He had authored/edited several books published by world renowned publishers, like Dr. W Junk of The Hague, Arnod Heinmann, CRC, ICAR, etc. Dr. Prakash was a widely traveled scientist. In pursuance of the knowledge of Mammalian Ecology of Thar Desert, he visited several countries as far away as Australia, New Zealand, USA, Thailand, Philippines, U.K., France, China, USSR, Kuwait and Italy.

Dr. Prakash had his own way of winning friends and influencing people by the charm of his innate calm and pedigreed manners. He was a combination of an eminent scientist, a great administrator and a perfect gentleman. He will always be remembered not only by those who had the privilege working with him but also by those who had ever corresponded with him.

Due to his sudden demise the Scientific World has lost a great environmentalist.

Contents

AICRP ON RODENT CONTROL - A PROFILE

B.D.Rana and R.S.Tripathi
Central Arid Zone Research Institute, Jodhpur

1. Historical Background

Rodents being a serious competitor of mankind cause immense losses 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, 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 Vishwa 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. Parmar University of Horticulture and Forestry, Solan (during VII Five Year Plan).

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 baits.

(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 in economically important rodents with a view to investigate ways and means to remove its derogatory influence on control operations 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, pulses, oilseeds, plantation 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. Organisation and Structure

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

Table 1. Organisational set up of AICRP on Rodent Control

S. No	Centre	Located at	ICAR/SAU of start	Year	Period of operation (years)
1.	Jodhpur (Raj.)	Central Arid Zone Research Institute, Jodhpur.	ICAR	1977	25
2.	Ludhiana (Punjab)	Dept. of Zoology, Punjab Agricultural University, Ludhiana	SAU	1977	25
3.	Kasargod (Kerala)	Central Plantation Crops Research Instt.Kasargod	ICAR	1977	25
4	Bangalore (Karnataka)	Dept. of Entomology, University of Agril. Sciences, Bangalore	SAU	1977	25
5.	Barapani* (Meghalaya)	Div. of Entomology, ICAR Research Complex for NEH Region, Barapani	ICAR	1982	20
6.	Lucknow* (UP)	Indian Institute of Sugarcane Research, Lucknow	ICAR	1983	19

7.	Jabalpur** (MP)	Dept. of Entomology, JN Krishi Vishwavidyalaya, Jabalpur.	SAU	1983	19
8.	Maruteru(A.P.)	Agril. Research Station (ANGRAU), Maruteru (West Godavari)	SAU	1986	16
9.	Solan (H.P.)	Dept. of Entomology, Dr. YSP Univ. of Hort. & Forestry, Nauni, Solan	SAU	1987	15
10.	Junagadh (Gujarat)	Dept. of Entomology, College of Agriculture, Gujarat Agril. University, Junagadh	SAU	1987	15
11	Jorhat (Assam)	Assam Agril. University,Jorhat	SAU	2001	02

Note: Kasargod Centre is not functioning due to non -availability of Scientific staff.

* Acting as Voluntary Center

** Center closed in 2001

4. Areas of Research : Besides multi-locational 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 technologies (Table 2).

Table 2. Specific areas of research at various centres

Name of the Centre	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, Cardamom etc.
ICAR Research Complex for NEH Region, Barapani (Shillong)	NEH crops (paddy, maize, pineapple)
J.N. Krishi VishvaVidhyalaya, Jabalpur	Pulses crops (gram and soybean)
Acharya N.G.Ranga Agricultural University, Maruteru (West Godavari district)	Wetland paddy
Indian Institute of Sugarcane Research,	Sugarcane-wheat-mustard

Lucknow (Sardarnagar, Gorakhpur)	
Gujarat Agricultural University, Junagadh	Groundnut
Dr. Y.S. Parmar University of Hort. and Forestry, Nauni (Solan)	Horticultural crops
Assam Agril University, Jorhat	NEH crops

5. Group meetings/Workshops : Organisation of the group meetings/workshops is one of the major objectives of the Project to assess the achievements, workout the recommendations of rodent management and to finalise the future research programmes after through discussion among various rodent scientists drawn from the coordinated Project and self funded centres. So far 10 All India Workshops/ Group Meetings have been organized by AICRP on Rodent Control at different Cooperating centers as detailed below:

1. Central Arid Zone Research Institute, Jodhpur (July 8-10, 1978).
2. University of Agricultural Sciences, Bangalore (August 18-12, 1980).
3. Central Arid Zone Research Institute, Jodhpur (March 14-16, 1983).
4. Indian Institute of Sugarcane Research, Lucknow (November 28-30, 1985).
5. ICAR Research Complex of NEH Region, Shillong (February 24-26, 1985).
6. Dr. Y.S.P. University of Hort. & Forestry, Solan (April 12-14, 1990).
7. Central Arid Zone Research Institute, Jodhpur (November 13-14, 1991).
8. Gujarat Agricultural University, Junagadh (December 29-31, 1994).
9. University of Agricultural Sciences, Bangalore (January 9-11, 1997).
10. Central Arid Zone Research Institute, Jodhpur (October,6-7 . 1999).

The Eleventh Group Meeting is also being held at Central Arid Zone Research Institute, Jodhpur (November, 12-14 , 2002).

6. National Symposium : A two day National Symposium on Rodent Pest Management - A Scenario for the 21st Century was organised at CAZRI, Jodhpur during November 15-16, 1991.

HISTORY OF RODENT RESEARCH IN INDIA

R.S.Tripathi and Vipin Chaudhary
Central Arid Zone Research Institute, Jodhpur

Rodents, especially rats and mice have always been with us, mostly as pests, ever since the primitive man started settled life and initiated agriculture. Porcupines, the largest rodent of the country and capybaras of Brazil (*Hydrochorens hydrocheris*), the largest living rodent of the world must have been a welcome sources of food. In Indian mythology, the rat is the mount of Lord Ganesha. These tiny vertebrates, have attracted the attention of naturalists in India for a long time, but the work carried out was mostly of general nature. In the early part of the last century, rodent work was intensified largely due to the spread of flea borne bubonic plague epidemic, the rat being the reservoir of infection as primary host. Thus most of the work during this period was of epidimeological nature. In the same period, survey and taxonomic works received a great fillip, when Government of India initiated "Mammal Survey Programme".

Survey and Taxonomic Studies

W.T. Blanford, a British naturalist, was the first man to publish volume on Mammalia as "Fauna of British India Series" (Blanford 1888-91), wherein he presented a comprehensive account of rodents of the Indian region. In this series he included the order Rodentia proper (the Simpticidentata) and the Lagomorpha (the Duplicidentata) in one group. Simplicidentata covered 93 species and 14 varieties. The next major taxonomic contributions were the 3 volume work of Ellerman (1940-49) as "The Families and Genera of Living Rodents". Ellerman and Morrison-Scot (1951, 1953) published a checklist of rodents also. In 1961, Ellerman published an other volume as a second edition of Blanford's Mammalia volume. This volume contains an appendix by Roonwal and Biswas also and is considered to be a standard work on Indian rodent fauna. It included 46 genera, 128 species and 260 sub species. Since then, a few genera and species have been added to the list of Indian rodents. In later years Zoological Survey of India continued to explore the rodent faunal diversity of the country by publishing fauna volumes, occasional papers and research reports. Biodiversity conservation Prioritisation Project, India undertook the work on conservation status of Indian rodents during the Conservation Assessment and Management Plan (CAMP) workshop in 1997. As per the latest information 102 species of rodents are reported to inhabit the Indian region, of which 15 species are endemic and 12 are monotypic.

Public Health

Large scale spread of plague epidemic in Europe and Asian continents led to the search of causal bacterium, plague bacillus by Yersin and Kitasato in 1894. The epidemics led the initiation of studies on rodents as vectors of the disease. Haffkin's Institute, Bombay was established during this period and the anti plague vaccine was discovered by the Institute. Between 1897-1903, Simondo and others could establish the relationship between fleas and plague and the transmission of disease. About the time of first world war Indian workers became actively engaged in the field of rodent research and control. Plague Commission was appointed by the Government of India in 1912. Besides the establishment of Haffkin's Institute in Bombay, the All India Institute of Hygiene

and Public Health, Calcutta, the Central Food Technology Research Institute, Mysore, the National Institute of Communicable Diseases, Delhi and the John Hopkins University, Rodent Centre, Calcutta were established to conduct epidimeological studies on rodent borne diseases. Rodents have been reported as reservoirs of several disease such as plague, rabies, tularemia, scrubtyphus, tide typhus, leptospirosis, leishmaniasis etc. In 1965 Ministry of Health, Government of India appointed a committee for National Rodent Centre, under the chairmanship of the then Dy Minister of Health. During the larger parts of 20th century India has been free from human plague for a considerable period, the research on rodents vis-à-vis public health was practically ceased. However, with the resurgence of plague in Gujarat (1994)and Himachal Pradesh (2001), the Government of India has initiated research programmes on these lines. However, NICD, Delhi, National Institute of Virology, Pune and some other ICMR Institutes are taking up studies on this aspect. Recently Expert Committee on Rodent Control has recommended NICD and ICMR to initiate collaborative research works with ICAR and Directorate of Plant Protection Quarantine and Storage.

Studies on Pre and Post Harvest losses

During 1960's, the havoc caused by rodents, at almost every stage of agricultural operation came into focus of Indian rodentologists and Government of India. During this period Indian Council of Agricultural Research initiated two centers for rodent research in the country. One was at Kanpur (U.P.) where a coordinated scheme on study of field rats was launched in 1959 under the supervision of Dr. A.S. Srivastava. The scheme operated at five centers viz., Kanpur, Ludhiana, Bombay, Hyderabad and Aduthurai. The scheme lasted for 11 years (1959-69). The second and the most prestigious centre on rodent research was initiated at Central Arid Zone Research Institute, Jodhpur, with the establishment of a separate section of Animal Ecology in 1959-61 under the leadership of Dr. I. Prakash. CAZRI, Jodhpur took a lead in rationalizing the philosophy of rodent control at National level. The Institute organized a Summer Institute on Rodentology in 1975 and launched a National Program on Rodent Management in the same year. Just after two years, that in 1977, ICAR launched an All India Coordinated Research Programme on Rodent Control at Jodhpur and Dr. I. Prakash took over as the founding Project Coordinator of the project. In later years the Project was headed by Dr. P.K. Ghosh and Dr. A.P. Jain and presently Dr. B.D. Rana is the Project Coordinator. The project ran at 11 centres spread in all major agro ecological regions of the country viz., Jodhpur, Ludhiana, Bangalore, Kasaragod, Shillong, Lucknow, Jabalpur, Maruteru, Junagadh, Solan and Jorhat.

During early seventies Ford Foundation of USA also funded a research project on rodent control at UAS Bangalore in 1973. A large scale rodent control campaign was also initiated in 1970 by Young Farmers' Association in Sidhpur (Gujarat) with financial assistance from USAID. Later, this project was supported by ICAR with PL-480 funds. The campus was spread over 82 villages in northern Gujarat. It is probably one of the largest demonstration work undertaken in the field of rodent control in India.

Symposia/Seminars organized in India

1. Calcutta : 1966, Indian Rodent Symposium, Calcutta, Dec. 8-11, 1966.

2. Kanpur : 1968. International Symposium on Binomics and Control of Rodents (Kanpur,

September-October, 1968).

3. Jodhpur : 1975. Summer Institute on Rodentology (Jodhpur, June-July, 1975).

4. Ahmedabad : 1975. All India Rodent Seminar (Ahmedabad, Sidhpur, Sept. 1975).

5. Jodhpur : 1991. National Symposium on ' Rodent Pest Management - A Scenario for the 21 st Century ' Jodhpur (Nov.15-16,1991)

Besides these 10 All India Workshops on Rodent Control have also been organized by ICAR at Jodhpur, Solan, Shillong, Bangalore, Junagadh, Lucknow etc. in different years.

Department of Food of the Government of India too is engaged in conducting research on storage losses caused by rodents and their management through their National network of Save Grain Campaign offices.

Rodent Newsletter, a quarterly publication of the project is also under publication since last 25 years and is always in great demand from India and abroad.

Publications

Based on the studies conducted on various aspects of rodent pest ecology and management, the Scientists have authored several research papers, popular articles, chapters in books etc. Technical Bulletins/ Monographs published by the Project are listed below:

- Ecology of Indian Desert Gerbil, Meriones hurrianae (1981). Central Arid Zone Research Institute, Jodhpur. 87 pp.

- Evaluation of Second Generation Anticoagulant Rodenticides in India I. Bromadiolone. (1986) Central Arid Zone Research Institute, Jodhpur. 20 pp.

- Evaluation of Second Generation Anticoagulant Rodenticides in India II. Brodifacoum. (1988) Central Arid Zone Research Institute, Jodhpur. 27 pp.

- Glue Traps : An Evaluation Report .(1988) Central Arid Zone Research Institute, Jodhpur. 12 pp.

- Rodent Pest Management: A Training Manual. (1988) Central Arid Zone Research Institute, Jodhpur. 67 pp.

- Social Engineering Activity on Rodent Control: A Case Study. (1988) Central Arid Zone Research Institute, Jodhpur. 17 pp.

- Chooha Prabandh : Eak Awasyakta, Kyon aur Kaise? (1988) Central Arid Zone Research Institute, Jodhpur. 24pp.
- Major Rodent Pest of Agriculture: An Illustrated Guide. (1988) Central Arid Zone Research Institute, Jodhpur. 14pp
- Rodent Management: The State of Art . (1993) Central Arid Zone Research Institute, Jodhpur. pp 34.
- Fifteen Years of Coordinated Research on Rodent Control (1994) Central Arid Zone Research Institute, Jodhpur. pp 144.
- Rodents and other Vertebrate Pest Management in Coconut and Cocoa. (1995) Central Plantation Crops Research Institute, Kasaragod. pp 28.
- Rodent Pests and their Management in North Eastern Hill Region. (1995) ICAR Research Complex for NEH Region, Barapani. 35pp.
- Recent Advances in Coordinated Research on Rodent Control (1999). Central Arid Zone Research Institute, Jodhpur. 48 pp
- Quarter Century of Research on Rodent Control in UAS, Bangalore. University of Agricultural Sciences, Bangalore. 126 pp.
- Rodent Management in Poultry Farms (1999) Central Arid Zone Research Institute, Jodhpur. 11pp.

ECOLOGY OF INDIAN DESERT RODENTS

R.S. Tripathi, Mohd. Idris and B.D. Rana
Central Arid Zone Research Institute, Jodhpur

Rodents constitute one of the largest mammalian group in this region, exhibiting a plasticity in respect to their choice of wide spectrum of desert habitats. Has enlisted 18 Rodent species belonging to 11 genera and three families, which in habited this region. A brief account of these species is as under.

Family Sciuridae : This family is represented by one species of five striped squirrel, Funambulus pennati, which occurs in orchards, gardens, forest nurseries and residential premises.

Family Hystricidae : The Indian crested porcupine, *Hystrix indica* is the only hystricid occurring in the arid regions of the country. It inhabits the hilly out crops in the crevices or the tunnels made by item.

Family Muridae

(a) Sub family Gerbillinae: Four species of gerbils occur in this region. Of them there are exclusively the denizens of arid areas. They are Indian desert gerbil, *Meriones hurrianae*: hairy footed gerbil. *Gerbills gleadowi* and Wagner's gerbil, *Gerbillus nanus*. The fourth species Indian gerbil, *Tatera indica* also inhabits the desert biome, besides its presence in other regions of the country as well. *M. hurrianae* is a diurnal rodent and other are nocturnal.

(b) Sub family Murinae : In all twelve species of this group are known from Indian desert. Amongst these two commensal in habits viz. *Rattus rattus and Mus musculus* which are widely distributed in residential premises of this region too. Three more species of Mus i.e. M. cervicolor, *M. platythrix* and *M. booduga* occur as wild forms in this regions. In the recent years *M. musculus* has been reported in the crop fields also in Punjab and Sri Ganganagar district of Rajasthan. *M. cervicolor* and *M. platythrix* inhabit the rocky habited and M. booduga in crops fields. Another mouse *Vandeleuria oleracea* (a tree mouse) has also been reported from this region.

Besides the *Rattus* rattus, three mouse species Rattus occur in north-western arid zones they are the Cutch rock rat, *R cutchicus cutchicus* (rocky habits), the soft furred field rat, *M. meltada* pallidior (in irrigated crops fields and grass lands), and the sand cloured field rat, *R. gleadowi* (in sandy plans). The monotypic Golunda ellioti gujerati (the bush rat) occurs near the crop fields and grasslands. The lesser bandicoot rat, Bandicot bengalensis is also found in arid areas (except in the extreme arid district of the desert), however, its population have been established in Biakaner town in recent years. The changes in landuse pattern in the Western districts of Rajasthan due to incoming of Indiara Gandhi Canal is helping the spread and establishment of this aggressive species in the canal command areas (Sri Ganganagar and Bikaner district). Another mole rat Nesokia

indica a north Indian species have also been reported to occur in the forest plantation of arid areas. In recent year it has been found to cause serious damage to the arid forestry plantation.

Habitat Preference

From the point of view of rodent distribution, classified desert biome into four distinct habitats, such as sandy, gravel plains, rocky and ruderal habitats. The sandy habitat occupies the largest area and is interspersed with stabilized and unstabilised sand dunes. The gravel plains are usually situated on the foothills of hillocks, except in Jaisalmer region where extensive gravel plains occur. The rocky habitats are found all over the desert but cover comparatively larger areas in the north eastern part. The ruderal habitat (the village complex) is scattered almost in all parts of the desert depending upon the availability of drinking water.

Rainfed crops are mainly grown in the vicinity of villages while in some areas irrigated cropping is also being practiced. Rodents are found in almost all these habitats. They are more abundant in the 100 mm rainfall zone in the western most sector of Rajasthan desert. The ruderal habitat is very well inhabited by rodents due to maximum availability of food, shelter and water under the influence of man and his livestock.

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

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 prefer rocky habitat. An overall analysis of the frequency of occurrence of 14 rodent species in different desert habitats revealed that 4 species share rocky and sandy 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 together.

It may be concluded that *M. hurrianae* and *T. indica* are the most abundant rodent species followed by R. meltada pallidior, R. cutchicus cutchicus and G. gleadowi. Other rodent species are represented comparatively in lower numbers. Established following sequence of rodent abundance in different desert habitats :

In sandy habitat : *M. hurrianae>T.i. indica>G.gleadowi>R.m. pallidior.*

In gravel habitat : *M. hurrianae>T.i. indica>M.P. sadhu.*

In rocky habitat : *R.c. cutchicus> M.P. sadhu>M.C. Phillipi>F. pennanti.*

In ruderal habitat : *T.i. indica>R.m. pallidior>M. hurrianae>G. gleadowi>F. pennanti.*

Food Habits

Rodents are generally herbivorous animals and prefer seeds but may feed upon insects and other animal food occasionally. At times they may even be cannibalistic. The palm squirrel, F. pennanti consumes fruits, insects larvae and bird eggs. Studies on stomach contents analysis of desert rodents indicated a clear cyclic pattern in their food habits. T. indica prefers seeds during winters and rhizomes and insects during summer, stems, leaves, flowers etc. are eaten all the year round. The desert gerbil, *M. hurrianae* chiefly thrives on seeds but during monsoon, it switches over to leaves and shoots of green vegetation and to insects and rhizomes during summers. Our observations have revealed that both these gerbils prefer the plant species, particularly during monsoon, which are the major forage for the livestock. The occurrence of grass species like, *Lasiurus sindicus, Cenchrus ciliaris, C. biflorus* and *C. setigerus* and the tree species like *Prosopis cineraria, Ziziphus nummularia* and *Capparis* sp. in the stomach of gerbils evidently reflect a competition between these rodents and our livestock for resource utilization.

Activity Patterns

In Rajasthan desert, 70 per cent of rodents are nocturnal and are therefore, able to avoid the extreme heat of the day. Three species viz., *M. hurrianae, F. pennanti* and *G. ellioti gujerati* are essentially diurnal. Two commensal species, R. rattus and M. musculus are basically nocturnal but are active in day hours also. The diurnal species have adjusted their diet activity in such a manner so as to escape from both extremes of summer and winter seasons. For example, the diurnal *M. hurrianae* changes its activity on bimodal patterns during summers and ventures out of its burrows in morning and evening hours only. However, in winters, it is active throughout the day except the very cool hours during mornings and evenings. Burrowing patterns of the desert rodents is also governed by the circadian rhythms of the species. The diurnals construct highly extensive burrows whereas, the eight dwellers have simple burrows. Besides beating the harsh climatic vagaries, the extensive burrows of diurnal rodents provide added safety to the inhabitants from natural enemies.

Breeding Season and Litter Size

Most of the rodent species, on which quantitative data about their reproduction biology is available, bred all the year round and their production potential, is very high. The desert rodents are able to regulate their breeding activity in consonance with the prevailing climatic conditions, food availability and social interactions. The peak number of xeric rodents breed during monsoon when the climatic conditions are most conducive and the availability of green food is high. The periodicity of littering bears a relationkship with day length since the littering activity start during late summers when the actual temperatures are high and the day length is maximum. Generally, rodents do not breed during extreme winter months when the day length is shortest or the prevalence of pregnancy is lower. Moreover, the litter size of rodents is largest during monsoon., as in *T. indica indica, M. hurrianae, F. pennanti, R. meltada pallidior* and *R. cutchicus cutchicus.*

Ecological Takeover

During the last 100-150 years the entire Indus Basin covering the states of Punjab, Haryana and northern Rajasthan have witnessed great ecological transformation with respect to soil, vegetation and land use patterns. These changes in Punjab, and northern Rajasthan (Sri Ganganagar district) started with channelisation of river waters. Major canal system in Sri Ganganagar district of

Rajasthan are Gang canal (1927-28), Bhakhra canal (1951-52) and Indira Gandhi Canal) 1056-57). Prior to irrigation system, desert represaented a true dry deciduous scrub jungle swhere sands with undulating sand dunes were the characteristic topography of this area. The climate, soil and vegetation was similar to today's arid region of western Rajasthan. Low shrubs and thorny bushes of Acacia jacquemontii and Capparis deciduas and trees like Salvadora oleoides and Prosopis cineraria, the floral indicator of sandy soil were very common. Among the herbs species like Salsola foctida and S. fruiticosa on saline soil and *Crotalaria burhia, Leptadenia pyrotechnica, Sericostema pauciflorum, Calligonum polygonoides, Aerva tomentosa* etc. on sandy soils were present in vast stretches. It is evident from earlier reports that the Indian desert is quite rich in rodent species due to Saharan and Iranian affinities of most of the species. Since river waters are being channelised in this desert on a large scale, the vast sandy stretch comprising of grasslands are being converted into crop lands. These changes in land-use pattern have threatened xeric rodent fauna to a greater extent. The phenomenon of ecological transformation of rodent communities can be well explained on existing scenario of Punjab, which is under irrigation agriculture since last 150 years and northern Rajasthan, which is under irrigation since more than 60 years. Sri Ganganagar district in northern Rajasthan forms the south eastern limits of the Indus basin. This represents a type of transitional zone for such transformation. Prakash et al. (1971a) indicated predominance of *T. indica* (44.7%), *R. meltada* (21.1%) and *M. hurrianae* (15.8%) and grouped them under the category of abundant species. *M. musculus* and *N. indica* with 7.9 per cent occurrence each were referred as common and *F. pennanti* and *G. nanus* were not observed at all. Our recent studies in this district revealed that *M. hurrianae*, another xeric species has been further driven away from irrigated crop fields to more sandy and drier areas of the district where irrigation is hardly 30-35 years old. Have observed large populations of *M. musculus* in sugarcane and cotton fields in Sri Ganganagar. *N. indica* and *B. bengalensis*, true mesic species were found in irrigated crop lands and fruit orchards. *R. meltada* has acquired the predominant status in the crop fields by *T. indica*, Mus sp., *B. bengalensis* and *N. indica*.

Within a short span of 60-65 years, the desert elements *(Gerbillus and Meriones)* found in the xeric environment have been replaced by mesic forms *(R. meltada, Bandicota and Nesokia)* in irrigated cropland of Sri Ganganagar district. Another xeric species, T. indica has so far been successful in adapting new environments. Diversity of rodents represented by 12 murid and one scuirid fauna recorded from the desert biome in sandy and ruderal habitats. Have been reduced to nine in the irrigated croplands of Sri Ganganagar district. Among this nine, many xeric elements do not figure but include three new mesic forms.

In phase II of Indira Gandhi Canal command area in parts of Bikaner and Jaisalmer district where irrigation is very recent, species composition of rodents is still amost similar to those reported by Prakash et al. (1971a). Near the canal banks where large scale afforestation of Eucalyptus, *Acacia, Dalbergia* and *Tecomella* undulata has been taken up, the predominance of squirrel *F. pennanti* easily noticed even in Bajju, Nachna and Mohangarh areas.

Thus, the desert elements like *Gerbillus*, and Meriones are under constant threat from the elements, like *R. meltada, Bandicota* and *Nesokia* due to transformation of sandy grasslands into irrigated croplands. Changes in their relative abundance vis-à-vis changed land use pattern clearly indicated faunal diversity of rodents would decrease. The species which vanish early are *G. nanus, G. gleadowi* and *M. hurrianae*.

BIOCHEMICAL COMMUNICATION AMONG DESERT RODENTS

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Out of 20 species of rodents inhabiting the Thar desert, the scent marking gland predominantly occurs in three species, two gerbils, the Indian desert gerbil, *Meriones hurrianae* and the Indian gerbil, *Tatera indica*; and in the soft-furred field rat, *Millardia meltada pallidior*. The desert gerbil is found only in the desert region whereas the two other species are distributed all over India. The gland is located on the posterior ventrum of these rodents. It is a glandular pad present in both the sexes of the two gerbils but is absent in females of *M. meltada*.

Mid Ventral Gland of *Meriones hurrianae*

The gland is ovoid in shape, broader anteriorly in males but is of more elongate shape in female gerbils. The gland pad can be readily seen by pushing aside the overlying lateral hair. The yellowish waxy exudation in the gland surface feels oily and has a distinctive musky odour more or less like that of Kasturi of the musk deer, *Moschus moschiferus*. When the exudation is removed with chloroform, the gland has a multipore appearance. Groups of short backward-pointing hair emerge from the pores, particularly towards the edges of gland pad. The gland is composed of complexes of enlarged sebaceous alveoli of typical holocrine type, each with its own duct. The gland units are separated from each other by thin layer of connective tissue which also supports the walls of the ducts which are lined with stratified squamous epithelium. The surface is, however, lined with cornified epithelium. The lower end of each duct opens into several sebaceous alveoli. The basal alveolar cells are small but as they develop they become progressively enlarged, their nuclei shrink and disappear and the cells break down into fatty detritus within the lumen of the duct. The holocrine secretion collects in a common duct through which the hair also passes. The hairs have flattened curved surface which is considered important for the movement of sebum out of the ducts.

The gland is significantly ($P < 0.001$) larger in males (gland area = 109.31 + 13.3 mm2) than in female *M. hurrianae* (41.6 + 3.7 mm2). The length, width and area of the gland was found to be highly correlated with body weight as well as head and body length in both the sexes ($r = 0.43$ to 0.91, $P < 0.001$). Analysis of variance of gland area revealed effects of sex ($F_{1.33} = 10.9$, $P < 0.001$), body weight class ($F_{1.33} = 43.2$, $P < 0.001$) and their interaction ($F_{1.33} = 7.8$, $P < 0.01$).

The ventral scent marking gland of the desert gerbils, M. hurrianae grows throughout their life as is evidenced by the relationship of gland area of male and female desert gerbils with their body weights. The gland size did not differ significantly between subadults of two sexes but in all the heavier body weight classes male desert gerbils had longer glands and with larger area than females, more so in 81 - 100 g body weight class, corresponding to 9-12 months of age.

It is evident that gland size increased markedly in both males and females upto 80 g body

weight and thereafter increased significantly only in male. When gland length and width were regressed separately against body weights for each sex and the regression coefficients for each measurement compared between sexes, males differed significantly ($P < 0.05$) from females in the slope of regression of gland width with body weight (male : $y = 1.53 + 0.513x$, female : $y = 0.370+0.0548x$), but not in that of gland length (male : $10.70 = 0.1326x$, female : $2.59 = 0.2150x$).

Change in frequency of occurrence and gland size in a captive population of *M.hurrianae*

A few desert gerbil, M. hurrianae were transported to Central Food Technology Research Institute, Mysore from the Thar desert. Though at Jodhpur littering seldom occurred in laboratory cages but at Mysore, in an air conditioned laboratory the desert gerbils bred profusely and a fairly large colony of progeny of laboratory bred rodents has been built up. The glands of 47 male and 45 female desert gerbils of F5 born to laboratory born parents were measured in relation to their body weight and known age. For comparison, similar observations were recorded on wild caught M. hurrianae at Jodhpur.

In the free living population in nature, the scent marking gland is found in all male and female desert gerbils, weighing more than 24 and 30 g respectively but in the laboratory-bred (LB) population of Meriones hurrianae, only 22 males possessed the gland out of 47 examined (body weight range, 40-130 g). Likewise only 22 females exhibited the gland out of 45 examined (45-140 g). Among male gerbils of LB population in the body class 61-80 g group the gland was found in 3 out of 10 rodents but in higher body weight categories, the presence of the gland was 100%. The corresponding figures in the females were 0 out of 7 in 41-60 g weight class and 3 out of 19 in 61-80 g group.

Wide variation was found in the relationship of body weight and gland size between the two population. In the LB population, the minimum body weight wherein a gland could be detected was 69 g in male and 76 g in female. However, in the wild population the gland occurs in gerbils as low as 24 g male and 30 g female.

Among the free living M. hurrianae the data indicate an increasing trend of the gland size corresponding with the body weight of the animals. In the LB population, this trend is true for male animals but a declining trend is seen in the gland size with the increase in body weight among females except in the 121-140 g body class.

On an overall basis and also in every body weight class the scent marking gland of male desert gerbil of the LB population was found to be significantly larger ($P < 0.001$) in size than that of females. Similar dimorphic variation ($P < 0.001$) has been reported in the gland size in two sexes of wild desert gerbils. The absence of the scent marking gland in younger animals (lower body weight classes) was further examined in relation to attainment of sexual maturity in the desert gerbil. In spite of the fact that wild as well as laboratory born gerbils attain sexual maturity when they are around 40-45 g (male) and 50 g (female) in body weight there is a wide variation in the frequency of occurrence of scent marking gland in the two types of populations. The scent marking gland is clearly detectable in 100% rodents of wild population at the body weight of 24 g

(male) and 30 g (female), when they are still not sexually mature. However, in the LB population the sexually mature females with perforated vagina did not possess the gland in body weight class of 41-60 g whereas in the next body weight class only 3 out of 19 females exhibited the gland. Likewise none of the males in the LB population out of 22 rodents with scrotal testes in body weight class 41-60 g possess the gland and only 7 out of 10 possessed it in the next body weight class. These observation indicate that the younger animals even though sexually mature do not possess the gland.

Mid Ventral Gland of *Tatera indica*

Unlike the desert gerbil (restricted to the Thar desert), the Indian gerbil, T. indica is distributed all over Indian plains and inhabits almost all the habitats. It stays on in the spreading urban areas, in the open fields and even in well populated streets of town and villages. The sscent marking gland is situated on the mid ventral side of the rodent. It is elongate, dirty white in colour but is not so prominent as in M. hurrianae, neither the hairless surface of the gland pad visually appears to be so glandular as in the former species. In the female T. indica it is significantly smaller than that of males and appears as a thin line. The presence of scent marking gland was reported for the first time in the genus Tatera. The urban and grassland wild population differ in their social organization as they exploit different types of environment. Urban Indian gerbils are gregarious, up to 70 individuals living in a single burrow system while in the grasslands they are sparsely distributed (contact animals), living singly or in pairs in a burrow (distance animals). Possibly as a consequence of their social behaviour, the frequency of occurrence of the ventral scent marking gland differs in the two populations. The gland is found in 91.4% (N = 286 out of 313) males and in 38.5% of females (N = 60 out of 156) in the grassland population; but in 85.6 males (N = 160 out of 187) and in 3.2% of females (N = 5 out of 156) in urban population.

The growth of the ventral gland is a continuous process through the age of the Indian gerbil is evidenced by the comparison of glandular size of male rodents and the body weight classes. The 80 g body weight corresponds with 4 month old animals, up to 140 g to 8 months of age and above these weights, the growth curve so flattens that age could be 1 to 1.5 years. It is observed that the gland weight significantly spurts at the body weight of 80 g and 160 g. The Indian gerbil attains sexual maturity around body weight of 70 g indicating that scent marking activity starts prior to attaining sexual maturity.

The length, width and area of the scent marking gland in male T. indica are significantly and positively correlated with body weight ($r = + 0.22$, $P < 0.05$ to $r = + 0.84$, $P < 0.05$ to 0.001) (Table 2). The correlation coefficient between body weight and gland length ($y = 0.16 + 0.07x$, $r = 0.557$) and with gland width ($y = 0.172 = 0.026x$, $r = 0.832$) are statistically significant.

Mid Ventral Gland of *Millardia meltada*

The metad or soft-furred field rat, M. meltada pallidior is found in northern India whereas the other sub species, M.m. meltada occurs in southern India. In the desert region of Rajasthan, the pallid sub species inhabits the districts on the western foot hills of Aravallis, from Sirohi in south to Jhunjhunu district in northeast which receive more than 400 mm rainfall annually. Its preferred habitat is crop fields. It does not occur in the low rainfall western region of the desert.

The scent marking gland situated in the mid ventral position is present only in 71.86% male metads. It was reported for the first time in the genus Millardia. The glandular pad is ovoid, broader on the posterior side and is the largest among the three species. It is dirty yellowish in colour and is fairly covered with hair. In this species also the growth of the gland is throughout the life of the rodent, as indicated by its increasing size along with the body weight. The correlation matrix of body weight and gland length ($r = 0.437$, $P < 0.05$), gland width ($r = 0.557$, $P < 0.001$), and gland area ($r = 0.220$, $P < 0.05$) were found to be statistically significant. Male metads sexually mature at a body weight of about 45 g but the gland can be prominently observed in smaller animals of 30 to 40 g body weight. In this species, like M. hurrianae, the gland appears before the rodent attains sexual maturity.

The fluctuating frequency of occurrence of the scent marking gland in the three species raises several questions. In the wild gerbils, Meriones hurrianae, the gland is present in 100% male as well as females. But in F5 generation of the laboratory born rodents, its occurrence drops to 46.8% in male gerbils and to 48.8% in females. Likewise the wild rangeland dwelling Indian gerbil, Tatera indica, 91.4% males and 38.5% females possess it but in the same species living gregariously in urban habitat, the frequency of occurrence of the scent marking gland dwindles to 85.6% males and only 3.2% females. In the metad, Millardia meltada it occurs in 71.86% males but is absent in female metads. In the male metads also it is absent in a number of rodents of 51-60 g body weight category.

The absence of the scent marking gland from one group, usually the females, and from a certain proportion even in males, its delayed development in laboratory born rodents, is rather perplexing. It is normally expected that an anatomical structure which has developed during the evolutionary process with a definitive function should be present in one and all animals of both sexes, then why such a variation? The question remains to be answered as to how the function of the gland is being performed in rodents which are devoid of the scent marking gland. The author has tried to investigate the answer to this query but ended up with many more questions. This may be due to lesser need of olfactory communication in gregarious conditions. Similar situation has probably occurred in the laboratory population of Meriones hurrianae where younger animals though sexually mature do not possess the gland.

Scent Marking Behaviour

Scent marking with the ventral gland is performed by these rodents by pressing the ventrum to ground surface and dragging it in a forward direction with the head kept in an upward position. The forward movement is followed by a perineal drag through which they mark the ground or object with their urine. This act is performed by both sexes but with a greater frequency by females ($P < 0.05$) which are devoid of scent marking gland.

The sebum marking frequency of male desert gerbils, M. hurrianae has been observed to be of a higher rate ($P < 0.001$) than that of the females. In T. indica also the scent marking rate of males is twice ($P < 0.05$) that of the females possessing the gland. In large laboratory cages filled with sandy soil and in an oval rattery (13 x 7 m), several experiments were conducted on numbered rodents to study their behaviour. When lodged in a cage singly, both the gerbil species scent mark

at a significantly higher rate but as the group size was increased, the frequency declined. Almost a similar reduction was observed with respect of urine marking rate in both the gerbil species.

The result also indicate that frequency of scent marking in gerbils is inversely associated with the number of individuals per unit area suggesting a similar decrease in the rate of scent marking. Moreover, the normal scent marking activity decreased to about 50% when grouped and the number of rodents which scent marked in cages under varying densities also reduced to about 66.6% in density of three and 33.3% in density of 6,9 and 12 per cage (90 x 30 x 30 cm).

It is quite possible that the scent marking cues in Tatera indica inhabiting the scattered populations in desert grasslands serve in maintaining a minimum distance between two animals or pairs. This concept gets support from our finding about the diversity in the frequency of occurrence of the scent gland in two types of populations living in different social organization. The maintenance of a spatial distance between two pairs may be necessary not only from social interactions point of view but to minimize competition for food in consonance with the carrying capacity of arid land which suffers from almost a perpetual paucity of food.

The author has tried to explain this depressed behaviour of gerbils when in groups in several contexts. There may be lesser need of olfactory communication in laboratory pens where they live a gregarious social organization. Under this condition, auditory, visual and tactile contacts might be the major source of communication but when gerbils are sparsely distributed in nature, such contacts are ordinarily not possible, hence, an increased sebum marking activity in them.

Scent Marking and Social Hierarchy

Another factor which has come to light for explaining this difference in frequency of scent marking is their dominance behaviour. No sooner the rodents are grouped in laboratory cages or in the rattery a male or a female acquires dominance status through fighting, chasing and scent marking at a higher rate. This finding was further investigated by planning a series of experiments in plus mazes, glass cages and the rattery. In the rattery a grorup of 3 male and 6 female M. hurrianae was released. All of them were marked by toe-clipping and dye-marked to facilitate identification of each desert gerbil. Soon after release they started digging activity and in about 15 days time a cohesive social group was formed. The dominant male as well as female were identifiable because of the number of times others stayed away from them, and on the basis of their chasing activity, which is an important component of their aggressive behaviour as compared to fighting. The merion gerbil, it was observed in the rattery, scent marked near the burrows and on heaps of soil excavated by them. The behaviour was usually followed by acts as digging with fore paws and kicking the soil back by the hind paws. Whereas all the three males sebum marked, only the dominant female performed this act. The exclusive scent marking activity by the dominant female may result into attracting the dominant male for mating resulting into a genetic upgradation. Such a behaviour component performed exclusively by the dominant female M. hurrianae in a social group has not been reported in any other species of the genus Meriones.

Attempts were also made to substantiate the above observations by removing the dominant male from the social group established in the rattery. One of the subdominant males immediately

increased (t test, $P < 0.01$) its scent marking activity to acquire a dominant status. Later on when a strange male of same body weight was introduced the former doubled its scent marking activity besides fighting and chasing the intruder to a corner of the rattery. It appears that the saturation of the immediate environment with its own odour is an important factor for establishing dominant status.

The more severe magnitude of dominance in female M. hurrianae as demonstrated by sebum marking is visualized in the context of evolution of sociability and adaptive value of self regulating population mechanism where their numbers are kept below a maximum level by restricting mating to only a few males and the dominant female not allowing through social interactions the dominant male to mate with other females in the social group. It is also possible that the dominant female desert gerbil familiarizes the alpha male with its own odour thus obliterating other females from chance of mating.

Similar exercise was undertaken in the rattery with target animal being the Indian gerbil, Tatera indica indica. The frequency of scent marking in males was twice ($P < 0.05$) that of the females possessing the gland but the females - with or without scent marking gland - urine marked the surface and around burrow opening at a significantly higher rate ($P < 0.05$). The dominant male as well as female urine marked at a higher frequency than other members of a social group. It appears that the social organization in T. indica is based on multi-dominant animals of both the sexes. However, whether the presence of gland in some females provides them with a superiority over other females devoid of gland is not clear as in several social groups the latter category acquired dominance whereas the one possessing scent marking gland was found to be very low in social hierarchy. In female, T. indica, the function of scent marking is compensated by urine marking, as their sebum marking gland is very small compared to that of male Indian gerbils. Moreover, though their social organization is also male dominated, but all the female T. indica are equally aggressive as the males. The versatility in scent marking and many other behavioural adaptabilities, like omnivory may be one of the reasons of its presence in every habitat throughout India. The two Saharan elements Meriones and Tatera must have entered India, through the Thar desert but the desert gerbil could not extend its range beyond the xeric environment whereas T. indica continued to spread even in south and eastern India and has assumed the second predominance status in the fields.

The diurnal desert gerbil, M. hurrianae lives in complicated burrow systems in which almost a constant and comfortable temperature is maintained. After exposure to the hot outer environment during the day the rodent develops hyperthermia and it offloads the excessive heat load into the cooler environment of the burrow by intermittently visiting it. In this context, the glandular region could act as a "heat window", allowing an exchange of heat with the surrounding environment when sebum is exuded out. The scent marking process, thus assists homeostasis in temperature regulation besides chemocommunication. This function of the scent marking gland may explain the reduction of scent marking frequency when they are in cages and are grouped together since due to huddling the necessity for homeostasis also declines.

Scent Marking Response to Conspecific Odours

Behavioural responses of three rodent species towards conspecific sebum odour were studied

in plus maze, cages and in the rattery. The rodents were given choice to react to glass slide smeared with their own sebum odour, of strange male and strange female. A plain glass slide was placed on the opposite side of the cage or in a different arm of the plus maze as control. Surprisingly, no sex attraction was observed as males preferred the unisex odour as adjudged by their own scent marking frequency, no of visits and duration of stay. Only in the absence of same sex sebum odour, sthey preferred odour of opposite sex as compared to behavioural acts performed near the blank slide. Both sexes of M. hurrianae even preferred unisex sebum odour of another gerbil, Meriones unguiculatus which is not a sympatric species. This behaviour of M. hurrianae is almost similar to that of M. unguiculatus and M. tristami. Under similar choice test combinations, the Mongolian gerbils show a significantly preferential response toward odour derived from other males as compared toward female sebum odour. However, the females of M. hurrianae show a significant preference for female odour whereas females of M. unguiculatus and M. tristami do not indicate significant preference for the odour of either similar or opposite sex. In M. unguiculatus marking has a familiarizing function, assuring access to females during proestrus and hence giving the male a chance to be first on the scene during estrus. This hypothesis also does not explain the responses of female M. hurrianae which are similar to that of males.

Behavioural responses of three categories of Indian gerbil, T. indica (males, females possessing the ventral gland and females without it) indicate that they are attracted towards male sebum odour though magnitude of preference by females is of a relatively low order. In this preferential behaviour T. indica is similar to Meriones tristami and M. unguiculatus. When responses of two types of female T. indica, the female possessing the gland rate the strange odour and strange female odour almost at an equal level. Females devoid of gland also preferred odours of strange males but when the choice was between the odours of female with gland and male, the difference between their rating was not significant.

Only the male metads, Millardia meltada possess the scent marking gland. When given the choice to prefer odour of male sebum, both male and female metads were attracted towards sebum odour of male. The female metads urine marked significantly ($P < 0.001$) more times near the sebum carrying glass slides. As compared to the two gerbil species, only female metads (which are devoid of gland) exhibited preference for male odour.

In absence of clear sex attractant function of sebum odour in the three rodent species it has been explained that an animals own scent might act to "increase its confidence" in the environment. Scent marks provide 'homeliness' to the animals. It has been observed that in the field as well as in large rattery M. hurrianae and T. indica ventral mark the burrow openings quite often, especially before entering the burrow. These rodents also scent mark food containers, the grass clumps in their home range and any new object whether it is a stone or a wooden peg. From these observations it appears that the function of scent mark is more of a 'familiarisation' nature or to signal 'home' to the marking rodent or that of labeling the habitat for an animals own use in orientation. These odours may leave sufficient olfactory cues which might deter other conspecifics away from the occupied territory. Since food is scanty in the desert and its availability is a prime factor for their survival there is a keen competition for it. The scent marking of grass clumps in the field and food containers in the rattery by the two gerbils suggests a "food reservation" function of the sebum odour.

Sebum Marking in relation to Reproduction

The female desert gerbils, when in oestrus, escalate their scent marking frequency and it is perceived by male gerbils almost by doubling their marking activity. The average period of oestrous cycle in M. hurrianae is 6.2 days which was determined by examining vaginal smears. The scent marking behaviour of female desert gerbils was observed in glass cage (92 x 31 x 31 cm) for 15 minutes daily at 1100 hours. The introduced female scent marked in the clean cage briskly. For observing the response of male toward female odour of female in oestrus, pro-oestrus and dioestrus, after removing the female, a single male was introduced and its marking frequency was recorded for 15 min. Every test was carried out on 10 rodents and in every replication a fresh male and female were used. Experiments (control) were carried out simultaneously in separate cages to observe the response of male gerbils towards odours of dioestrus females.

The frequency of sebum marking by the female M. hurrianae increased significantly ($P < 0.01$) during pro-estrus and oestrus in comparison to that in dioestrus. It is inferred that their oestrus state is communicated by females through olfactory cues by escalating sebum marking activity which may serve to advertise their readiness to mate. The state, it appears, is perceived by male desert gerbils as they also increase the frequency of their scent marking in the area of odour deposited by pro-estrus and oestrus females to saturate it with his own sebum smell to attract the ready-to-mate female.

Status and Challenges in Rodent Control Research in India

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The population of India, estimated at I billion in 1999, is growing at an annual rate of 1.9% at this rate it would reach to 1.4 billion by 2025 requiring 380 million MT of food grains against the current production of 209 million MT. Rodents are responsible for 5-7% loss of food grains annually during production, storage and transport. With this rate we loos about 10 to 14 million MT of food grains annually at present. These losses may further increase with increased production and related many diseases to humans and livestock causing incalculable economic lossess. Therefore, rodent control should be considered as one of the key technology for food and health security of India. The All India Network project on Rodent Control, with its centres located in different agro-climatic zones, from its inception in 1977 as AICRP, has made highly significant contributions toward food and health security of the country as the technology generated and transferred from time to time for the pre-and post-harvest control of rodent pests in different agro-ecosystems, not only reduced major crop losses and outbreaks of rodent-bome diseases (plague, leplospirosis, salmonellosis etc.) but has also significantly checked the chronic losses by rodents to major crops like rice, wheat, sugarcane, groundnut, pulses, vegetables, plantation crops of coconut, oil palm etc. Extensive research carried out under this project helped us not only to understand the spatial and temporal distribution patterns of rodents and their relationship with different crops and economic impact, ecological and beahvioural adaptions and has also led to the development of mechanical and chemical techniques of their control involving area, crop and species-specific poson delivery systems and baiting strategies in different pest situations based on information generated through AINP multi-locational lesting of rodenticides and baiting materials. The date base particularly on different aspect like rodent diversity, ecology, behaviour, populatin and efficaiies of chemical compounds for rodenticidal action have improved our capabilities of tacking rodent problems effictively in different parts of the coutnry.

Achievements

- Major achievemnts of the AICRP/AINP since its inception in 1977 can be listed as below :
- Establishment of species diversity and population changes concomitant with agricultural developments during the era of Green Revolution.
- Determination of economic impact of rodents in different crops and cropping systems.
- Analysis of ecological and behavioural adaptations of different rodent species in different agro-ecosystems.
- Determination of feeding preferences and develoment of acceptable bait formulations by different rodent species.

- Study of breeding biology of major pest species and efficacy of reproduction control chemical compounds.

- Determination of laboratory and field efficacies of 17 different acute, sub-acute and chronic rodenticides and recommendation of compounds with board-spectum and species-specific effects.

- Introduction of second general anticoagulant rodenticides (brodifacoum, bromadiolne diferthialone flocoumafen) is a major contribution and some of these has been included in package or practices for rodent control.

- Determination of crop-wise schedules of rodent control in different agro-ecosystems.

- On-Fam evaulation and refinment of rodent control technology through social engineering programmes of the project greatly helped to improve the performance of rodent control operations.

- Data base generated for developing a suitable rationable for resiliency management of rodent populations with certain chemosterilants and bio-control agents.

Challenges

Rodents, being mammals, are intelligent pests with complex behaviours, long home range and high dispersbility and adaptability. Despite of significant advances inour knowledge about Indian rodents, the following challenges and gaps continue to persist impeting efforts for developing effective techniques for their long-term managment.

1. Thetropical and sub-tropical climates of India are conduive to reproduction and large population of rodents, resulting totheir frequent population irruptions particularly during favourable crop conditions. Thus, crop-and area-specific methods for forecasting of population irruptions and managment need to be developed.

2. Post-control resiliency has been identified as a major cause of sustainbility of rodent populations and also failure of control at farmer's fields compeling the farmers to adopt frequent aplication of rodenticides.Therefore, methods for management of post-control "left over" population need to be developed.

3. Change in land use and cropping patterns irrigation and agronomic practices drastically effect the composition of rodent communities and population dynamics, as for examples with increased rice cultivation in Punjab, Andhra Pradesh and Kranataka and improved irrigation in Rajasthan and Gujarat *Bandicota bengalensis* replaced *Rattus meltada* and *tatera indica*.These species differ behaviorally and in their ecological requirements, thus requiring different rechniques for their management. Therefore, in future our strategies of rodent control require to be changed periodically in view of the changes in cropping patterns and crop production techniques.

4. Genetic resistance to anticoagulant rodenticides and behavioural resistance to acute rodenticides imed success of rodent control. Effective solution for these problems need to be found which require detailed analysis of these processes and responses to different rodenticides.

5. Social engineering research on rodent control revealed that due to varied socio-political reasons village-level anti-rat camaigns have become difficult to be organized. Therefore, rodent control technology to the effective on small farms need to be developed so that smalland marginal farmers may protect their crops from rodent attack.

6. Rodents possess complex mechanisms to with stand abiotic and biotic stress and excellent benaviorual defense system to rodenticide treatements. Their inter and intra-specific communication and social behaviours impede efforts of their control with trapsand rodenticides. Therefore, semiobiology and social behaviours need to be studied to improve the success of rodent control programmes.

7. Post-harvest strorage and transportation need to be made rodent-free as any contanination of grans, vegetables and fruits and other food matcrials with facess, urine and hair of rats, which carry germs of certain diseases, may result to rejection of their export because some countries inspect their import for such contaminations. Therefore,rodent control technology of post-harvest storage need tobe improved and methods need tobe developed for monitoring contaminations.

8. Integratedrodent pest management (IPRM) is almost lacking and most of the control operations depend upon the use of rodenticides. With the knowledge of different aspects of ecology and iolgoy of rodents it will be possible in future to develop ecologically based rodent control approches.

RODENTS AND THEIR MANAGEMENT IN KARNATAKA

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1. Species composition.

It is essential to establish the species composition of a crop field to plan rodent control programmes as the activity pattern i.e diurnal or nocturnal, bait preferences, burrow patterns, persistence of bait shyness, breeding season may vary from species to species. Data on species was collected zonewise and cropwise for eastern dry zone, central dry zone, southern transition zone, northern zone, northern transition zone, hilly zone and coastal zone.

i. Zonewise species composition :

The different agro-climatic zones of Karnataka are characterized by specific cropping systems. Concurrently the species infesting and damaging crops will differ from region to region. The studies carried out from 1987 till date indicate that *B. Bengalensis* is major pest in all the zones except northern transition and central dry zones. *T. indica* was the second most abundant species in four zones namely eastern dry, central dry, southern transition, and northern zones, a while *M. meltada* occupied this status in five zones namely eastern dry, central dry, southern transition, southern and northern dry zones. The other major pests were F. palmarum in eastern dry and hill zones, R. rattus in central dry and coastal zones while Mus species, Hystrix indica and Funambulus tristriatus were predominant in only one zone i.e. Mus species in central dry and the other two species in coastal zone.

ii. Cropwise species composition in Eastern Dry Zone:

B. bengalensis was the major pest of paddy, ragi, soybean, redgram, sunflower, groundnut, sapota and pomegranate. T. indica infested maize, soybean, redgram, groundnut and sapota while the third major species was M. meltada in sunflower. Two species of field mice (M. platythrix and M. booduga) were minor species in pomegranate, sunflower, soybean and maize. Squirrel was a major pest in pomegranate.

2. Extent of rodent damage :

Amongst cereals, the damage was 6-12% to ragi, 4-7% at germinating/seedling stage of maize, 7% during cob formation of the same crop, 9-10% to paddy at milky stage and grain formation, 50.80% to germinating jowar and 5-10% to wheat at the time of harvest.

The damage to oil seeds was 30-40% at germinating/seedling stage of groundnut 4-9%, to mature pods. 30-100% to seeds sown/ seedlings of sunflower and 1-2% at seed formation stage of sunflower. Soybean was affected negligibly viz 06-0.77% pod formation stage.

Amongst pulses, in redgram 50-100% damage occurred at seedling stage and 2% at pod formation.

Ten per cent damage was seen during the vegetative growth of greengram.

Amongst horticultural crops moderate damage of 5% was caused to potato seedlings and 7% to potato tubers. Four percent of sweet potato tubers were damaged. Tomato and cucumber were damaged up to 10%. Field bean was damaged up to 8%.

Fruits like pomegranate and sapota were damaged up to 10% and 8% respectively.

Plantation crops namely coconut. Arecanut and cardamom were also damage by rodents. The loss was 5-10% to tender coconuts, 10-50% to mature nuts, 2.3% to arecanut at flowering stage and 12% to cardamom capsules. Other crops affected were 4% of mulberry and 80% of chrysanthemum during summer.

3. Evaluation of available rodenticides:

Evaluation of existing and newer rodenticides in terms of bioefficacy and duration of baiting is an essential step towards field rodent control. Based on extensive field and laboratory evaluation it was found that :

a. Amongst acute rodenticides, vacor, silmurin and barium carbonate cannot be used for rodent control as vacor is banned and the other two are not commercially manufactured.

Zinc phosphide, the only available, safe, cheap economic rodenticide at 1-2% in the bait results in 100% mortality of field rodents in laboratory tests and 70-80% mortality under field conditions. However it's use should be restricted to single day and only for field conditions as the poison is toxic to non-target animals.

b. Fumigants : Since use of single rodeniticides may not eliminate rodent pests satisfactorily, survivors of zinc phosphide poisoning can be killed using (a) The commercially available fumigant, Aluminium phosphide (0.5g tablet). One should be introduced per burrow if burrows are simple (b) If the burrows are elaborate with multiple openings, one tablet should be introduced into each opening (c) Survivors should be subjected to a second fumigation. (d) Rodent control by fumigation is effective only in irrigated crop fields.

c. Amongst the first generation anticoagulants, 0.025% ratafin and 0.025% rodafarin baited for 10 continues days resulted in 100% mortality of bandicoots, gerbils and house rat in the laboratory and 43-100% population reduction in poultry, paddy fields and coconut. Racumin at 0.06% was effective in laboratory evaluations.

Although second generation anticoagulants namely 0.005% bramadiolone, 0.005% brodifacoum, 0.005% flocoumafen and 0.0025% difethiolone were found more effective than first generation anticoagulants both in the laboratory, and different field conditions namely irrigated and rainfed crop fields, poultry, storage, commercially only bromadiolone is available as 'roban' and 'marten'. Brodifacoum, Flocoumafen and Difethiolone when become commercially availability can be recommended for usage. All the four second generation anticoagulants can be safely used in houses as well as in fields.

4. Bait shyness Studies :

Since wild rodents across world are known to avoid poison baits after ingesting sublethal does of acute rodenticides, it is important to understand whether Indian rodent pests also exhibit such a phenomenon. If so rodent control using zinc phosphide should use the exact lethal concentration of 2% poison and baiating should be restricted to single day. Further, it is also important to know if bait shyness extends to cereal, oil and other, components of poison bait. Since the major rodent pests of Karnataka development bait shyness after ingesting sublaethal doses of zinc phosphide and this bait aversion extended to cereal and oil component of the bait and the fact that bait shy rodents become neophobic led to the suggestions that (i) Rodent control using zinc phosphide should be restricted to one day (ii) Bait shy rodents should be poisoned with chronic rodenticides such as bromadiolone (iii) The subsequent use of zinc phosphide should be after 30 days in cases of *B. bengalensis*, 40 days later in fields infested by *M. meltada*, 70 days later in *R. rattus* infested areas, after 105 days in case of B. indica, 110 days later in gerbil infested fields and after 170 days in fields harboring *M. platythrix*.

5. Suitable and attractive bait carriers are necessary for effective poisoning of rodent pests. Based on preference exhibited by rodents towards cereals, texture of cereals, oils, different concentration of oils, 2% sugar, and 2% salt, the following baits are suggested for mixing with poison for different species- *B. bengalensis*. Broken rice+10%, M. platythrix. Whole ragi + 10% groundnut oil, *T. indica* whole ragi + 10% groundnut oil, M. booduga: Whole rice + 10% gingilly oil, *M. meltada*: Broken rice + 10% groundnut oil and *R. rattus*: rice + ragi + wheat + maize + jowar in equal proportion.

6. Behaviour relevant to rodent Control :

a. Neophobia : Avoidance of new foods or neophobia may render direct poisoning ineffective, as the rodents tend to avoid the poison food for the first 2-3 day. Later they may consume small quantities of poison food, which will lead to bait shyness. *B. bengalensis, T. indica, B .indica, M. meltada, M. platyttus*, and *M. booduga* exhibited avoidance of new foods for 3-4 days. R. rattus did not exhibit such behaviour probably due to the fact that living as a commensal in close association with humans and live stock, it is not phobic about new things. These results suggest that prebaiting with 2-3 days with plain bait is a prerequisite before poisoning rodents with acute poisons. In Mus platythrix, neophobiaa can be mitigated using dilute concentration of female urine.

b. Early nutritional experience : Early nutritional experience including prenatal flavours via mother's milk was found to influence adult food selection in *B. bengalensis* and *M. booduga*. Thus it is likely that cereals and oils grown in the habitat of a rodent pest species may become attractive and will be preferred to other cereals/oils. Therefore the cereal and oil prevalent in the host habitat can be effectively used to mix rodenticides.

c. Hoarding behaviour : Considerable amount of yield from standing crop is hoarded by rodents, which is an instinctive behaviour. Laboratory arusiwa insect size of the grain, nutritional status and sex of the animal influenced hoarding behaviour.

d. Grain losses by spoilage : Studies on grain losses due to spillage, consumption, hoarding and spoilage caused by *B. bengalensis. R. rattus, M. meltada* and *T. indica* under simulated laboratory conditions demonstrated than annual losses are greater in houses than in godowns and fields. Gerbils and bandicoots cause comparatively more damage than the other species.

e. Food deprivation is known to increase total activity of rodents to facilitate chances of encountering food in the animal's natural habitat. Studies indicated that hunger and thirst makes bandicoots more exploratory and also more aggressive.

f. Dominant-subordinate relations : Socially dominant species and dominant individuals of a species access food first and are likely to be killed first during poisoning.

A change in cropping pattern alters species composition with mortality of dominant species, Bandicota bengalensis. Consequently less dominant species like Mus booduga emerge as serious pests.

g. Aggressive behaviour : Studies revealed *B. bengalensis* to be the most aggressive rodent species followed by *T. indica,, R. rattus* and *R. norvegicus.*

h. Rhythms : Most rodents are nocturnal and exhibit peak activity at 1800 hrs. This observation signals that poison baiting of field rodents should be scheduled around 1600-1700 hrs.

i. Aversion behaviour : Flavors and dours aversion behaviour of rodents can be exploited to develop aversion towards susceptible food crops. Laboratory tests showed that water extracts of neem, pongamia, digitaliis and 0.01% cat's urine readily induced aversion in *B. bengalensis* towards its preferred food, rice. The urine of mice fed cat was more potent than that of milk fed cats in inducing aversion.

Breeding ecology of Rodent Pest Species in Karnataka

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Increasing food production is one of the most important challenges facing mankind to meet the requirement of growing human population. Efforts to bring more areas under agriculture every year is often encountered by pest population causing crop depredatin. It is established fact that vertebrate pest particularly rodent have been destroying the agricultural produce and the problem of their involvement in crop loass and damage have not been receiving much attention as that of other insect pests. The capital loss in agriculture is often never compensated by adapting crop protectin measures alone against vertebrate pests without considering the concept of integrated pest management practices.

Rodent are a chronic problm and a long term population reducion is not practical. Therefore annual control either at seedling or mature stage of crop is often necessary. They exhibit a regular seasonal cycle of fluctuations in numbers under the influence of environmental factors which change the balance between natality and morality. There are predictable times in a year and places where control can be most effective for reducing there damage. Studies on reproductive biology of rodent have given us definite clues so as to focus the initiation of rodent control programmes in the crop fields. So it is from this point of view the present review/study is aimed to present the information available on the breeding aspects of rodent pests occuring in different agro-climatic regions of Karnataka which will go a long way inplanning effective managment practices for rodents in cropped fields.

The breeding potential of five important rodent pest species of Karnataka revealed that the rodent pest exhibit a dfinite reproductive seasonlity commencing as early as on the onset of monsoon during September, Octover, November and December months. Further, the well documented scientific data establishes the fact the rodent breed during the monsoon when the weather/environmental factors such as rainfall, relative humidity, temperature, day length etc., are conducive enabling them to breed at a rapid rate. Thus reproductive breeding behaviour is also definitely governed by the presnece of abundant green vegetative food in the field soon after the monsoon.

On the other hand, as the season nears/reaches summer, the rodents exhibit lesser breeding ability due to unfavourable weather factors coupled with scanty available food material in the fields. A close insight into their breeding adpects points out that rodent field population is at base or minimum during the summer time i.e., March, April, May, June Months. Therefore, application of the knowledge on the rodent pest managment side has a greater advantage in terms of cost benefit ratio. Hence rodent control operation/campaigns need to be organized during summer month with use of limited inputs to achieve greater success. Killing one rodent pest during the period of April to July is almost like knocking down about 52 to 67 pest during the peak breeding period. Further, summer time or the period of initiation of field rodent control operations is invariably free from other occupational farm activities.

It is also equally important to practice the package of rodent control especially during pre-harvest stage of the crop, so as to protect the crop from rodent damage due to migration in search of food (preference) and habitat slection to breed and maintain their field population.

RODENTS OF HIMACHAL PRADESH

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Himachal Pradesh is located in the Himalayan mountain between 300 24'40"N and 30012'40"N latitude and 75004'55"E and 70004'20"E longitude. It constitutes a unique geographical area in as much as it embraces vastly distinct and diverse agro-climatic zones viz. wet-sub-temperate, humid sub-temperate, dry temperate-alpine high lands, humid sub-tropical and sub-humid sub-tropical zones, a very diverse land range (plane to sub-mountain to snow line and snow covered peaks) and diverse agricultural activities (traditional cereal crops to vegetables to orchards to forests). Being so much diverse in agricultural activities, the crops are attacked by many pest species, of these rodents are one of the most important pests. From Himachal Pradesh, 10 species of rodents have been reported, these are *Bandicota bengalensis, Rattus meltada, Rattus rattus, Tatera indica, Golunda ellioti, Mus mumculus, Mus booduga, Mus platythrix, Funambulus pennanti, Hystrix indica*.

The Indian mole rat, *Bandicota bengalensis* Gray

It is the most prevalent species in all the agro-climatic zones of Himachal Pradesh, right from the foot hills (300m above MSL) up to the height of 2500m above MSL. It is the major pest in all the regions. However, its population is low in Kinnaur area (dry temperate zone). It is primarily a field species which inflicts damage to cereal, vegetables and fruit crops from sowing/seedling/nursery stage onwards till maturity. In addition, it is also an inhabitant of the tea plantations, forests and waste/grass lands. In Kinnaur, its tendency to adopt commensal mode of life has been observed being present in the residential premises where apple and other fruits are stored. In pecan nut orchards, this rat was reported to be responsible for considerable damage. Whereas on cauliflower (both curd crop for culinary purpose and seed) the damage by *B. bengalensis, R. meltada* and *M. booduga* varies from 4.44 to 11.37% in curd crop and 6.51 to 13.94% in seed crop resulting in a net loss of up to 1755 Kg curd/ha and up to 53.67 Kg seed/ha, respectively. Tea plantations have also been reported to infest with *B. bengalensis, M. booduga, M. musculus* and *G. ellioti* whose activity adversely affect the quality and quantity of produce.

ii) The Soft-furred field rat, *Rattus meltada* Linnaeus

It is a field rodent which is distributed chiefly in humid sub-temperate, humid sub-tropical and sub-humid sub-tropical zones of the state. It is a pest on cereal crops (wheat, paddy, maize), sugarcane and vegetable crops and is also present in pecan nut orchards. reported that in citrus orchards both *R. meltada* and *B. bengalensis* dig elaborate burrows, damage root and bark of the trees ultimately resulting in reduction in the growth and vigor as depicted by reduced fruit set.

iii) The Common Indian rat, *Rattus rattus* Linnaeus.

It is primarily a commensal species and inhabits residential premises and stores where it constructs its nests using a variety of nesting material like cloth, paper, cardboards etc. It is present in all the agro climatic zones of the state. However, it is a frequent visitor to fields and is a pest on all types of crops growing near human habitat. In fields, it has been recorded from the burrows deserted by other rat species. Reported this species to be inhabiting in cauliflower fields in the mid hills of the Solan. It has also been recorded from the trees occupying the bird nests.

iv) The Indian gerbil, *Tatera indica* Hardwicke.

This species has only a limited distribution in Himachal Pradesh, having been recorded from foothills of district Solan only (humid sub-tropical and humid sub-temperate zones). It was recorded from vegetable field crops and wasteland.

v) The bush rat, *Golunda ellioti* Gray

It has been recorded from sub-temperate, humid sub-tropical and sub-humid sub-tropical zones up to an elevation of 1200m above MSL. Reported that this species of rodent is present in orchards and areas (waste land, forests etc.) supporting bushy and grassy ground cover. In apple, peach, plum and pecan nut orchards, it accounted for 13.95, 15.38, 13.51 and 7.55% of the total rodent population. Occasionally, it has been recorded from maize and cabbage fields where it may be a casual visitor.

vi) The House mouse, *Mus musculus* Linnaeus.

It is a commensal species which is a serious pest of all crops all over the state. It has carved out a niche successfully along with *B. bengalensis* in the orchards, nurseries, vegetables and cereal crops fields, sugarcane fields, grasslands and wastelands. It is also present in the tea plantation, granaries, stores and residential premises. In a survey study conducted in various districts of Himachal reported *M. musculus* to be the most dominant species both in orchards and vegetable crop fields. In apple, peach, plum and pecan nut orchards, it comprises 30.23, 32.69, 35.14 and 33.96% of the total rodent population.

vii) The Indian field mouse, *Mus booduga* Gray.

This field mouse is a common pest in all nurseries, orchards, crop field, tea plantations and grasslands up to an elevation of 2000m above MSL.. In cauliflower, reported it to be one of the major rodent species comprising 13.23% of the total rodent population in curd crop and 13.98% in the seed crop.

viii) The Brown spiny mouse, *Mus platythrix* Bennett

It is found in sub-humid tropical and humid tropical regions. It is also a commensal species and pest of forest trees and maize.

ix) The Five-striped squirrel, *Funambulus pennanti* Wroughton.

This species has been found in sub-humid and humid sub-tropical zones as a commensal species. It is a pest of fruit trees and maize crop. It can also be observed in large numbers among the mango and *Zizyphus* plantations and inhabits the holes in the trees and consumes fallen *Zyzyphus* fruits.

x) Porcupine, *Hystrix indica* Kerr.

It is widely distributed in various agro-climatic zones of Himachal Pradesh from the districts of Kangra, Mandi, Shimla, Sirmour and Solan up to an elevation of 2700m above MSL. It inflicts heavy damage to a variety of crops in the state, especially in the fields located near their natural habitat. Its attack, however is sporadic but extensive. It damages tuber crops, cabbage etc. and also the young pine plantations apart from other trees in natural forests as well as in afforested areas. In Shimla district, the porcupine damage in carrot, radish and potato has been recorded in different localities in the fields adjoining the forest strips whereas in Sirmour and Solan districts, turmeric and ginger rhizomes have been found to dug out. The damage to the young pine plants (*Pinus roxburghii*) by this species has been reported up to 90%. From Kangra district, the damage to mango and citrus orchards is found in the form of girdling and debarking due to gnawing habit of the animal, particularly in the orchards located near forest, wasteland or grassland and where wheat is sown as intercrop.

RODENT ECOLOGY AND THEIR MANAGEMENT IN GUJARAT

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Rodent species composition

Extensive survey work is going on in various habitats viz., residential premises, godowns, poultry farms as well as crop fields of different agro-climatic zones of Gujarat state. The major rodent species found during the survey are *Rattus rattus* (Linnaus), *Rattus cutchicus* (Wroughton), *Mus musculus* (Linnaeus), *Mus booduga* (Gray), *Millardia meltada meltada* (Gray), *Bandicota bengalensis* (Gray), *Tatera indica indica* (Hardwicke), *Meriones hurrianae* (Jerdon) and *Vandeeluria oleracea* (Bennett).

Relative abundance

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. cutchicus, M. musculus* and *Bandicota bengalensis* were found damaging bengalensis the stored products in godowns. Similarly, R. rattus, R. cutchicus and B.bengalensis also infested the poultry farms. Among these species, *R. rattus* was found predominant in 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 6.45% in houses and 3.43 to 6.60% in godowns) during September and October.

Field survey : Field surveys were conducted in five different agro-climatic zones of Gujarat state viz., North Saurashtra, South Saurashtra, Bhal and coastal area, North Gujarat dry region and Northwest zone. The gist of survey and monitoring is given below :

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 agro-climatic zones revealed that *Bandicota bengalensis* was predominant comprising 49.92 to 88.20 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 agro-climatic zone except in Veraval, Jetput, Rajula and Jafrabad taluka, where *T. indica indica* was found predominant with 42.27 to 75.38 per cent of population. *Mus booduga* was also found damaging the crop fields in some pockets of this agro-climatic zone. *B. bengalensis* was also found predominant (48.04 to 89.33%) in North Saurashtra agro-climatic 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* was found predominant species in majority of groundnut growing areas of South Saurashtra and North Saurashtra agro-climatic zones in Saurashtra region. In coconut plantation, *Rattus rattus* was found predominant species damaging the nuts followed by *Vandeleuria* sp.

In Bhal and coastal areas of agro-climatic zone, *T. indica indica* was found predominant species comprising 55.71 to 70.39 per cent of population in kharif season except in Dholka and Dhandhuka talukas of this agro-climatic zone, where *B. bengalensis* was found predominant with 67.81 per cent population which is due to deep black and salorthids soils of these talukas and it was followed by *M. meltada meltada* with 4.91 to 7.64 per cent population.

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, *T. indica indica* followed by *B. bengalensis* and *M. meltada meltada*. But in Sami, Tharad and Vav talukas of Northwest and zone and Dhanera taluka of North Gujarat-dry region, *M. hurrianae* was found predominant species (78.20 to 82.85%) followed by *T. indica* indica.

B. bengalensis was found to be predominant rodent species in almost all types of soil in groundnut growing area during kharif and summer seasons except in coastal alluvial + medium black + shallow black soil in kharif season and mixed red and black + shallow black soil in summer season. Other two species viz., *M. meltada meltada* and *T. indica indica* were found 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 + medium black + coastal alluvial and shallow black type of soils. On the other hand, *T. indica* indica was found predominant species in coastal alluvial + medium black + shallow black type of habitat during kharif season and it was followed by *B. bengalensis* and *M. meltada meltada*. In mixed red and black + shallow black soil, *M. meltada meltada* was present relatively higher in numbers, while the other two species viz., *B. bengalensis* and *T. indica indica* were found comparatively lower in numbers during summer season.

Types of irrigation also played an important role in relative abundance of *M. meltada meltada* and *T. indica indica* in South Saurashtra agro-climatic 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 season.

Rodent damage

Sudden multiplication of rodents and their population assuming menacing numbers happened in Gujarat state during the year 1975-76 and again in 1989-90. The intensity of rodent damage in field crops increased 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 sowing of summer groundnut during 1990 in most of the groundnut growing areas of the Saurashtra region.

Extent of rodent damage recorded during the year 1988 to 1990. The higher damage in all the field crops was recorded during the year 1989-90, when there was a severe outbreak of rodents.

Strategies developed for rodent management in field crops and poultry farm

Following packages are developed for the management of rodent in field crops and poultry farm :

i. Two applications of bromadiolone 0.005% wax cake, first at the time of flowering and second at pod maturity stage (ICBR 1:49.5) or first 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 (ICBR 1:24.8) each @ 10 g poison bait/live burrow are effective for rodent management in groundnut crop.

ii. Two applications of bromadiolone 0.005% wax cake, first at tillering stage and second at milky stage (ICBR 1:52.04) or first application of zinc phosphide 2% poison bait at tillering stage and second application of bromadiolone 0.005% wax cake at milky stage (ICBR 1:32.43) each @ 10 g poison bait/live burrow are effective for rodent management in wheat crop.

iii. For proper management of rodent population and reduction in crop losses in cultivated area, farmers are advised to treat the cultivated fields as well as barren land of nearby area by zinc phosphide 2% poison bait at flowering stage of groundnut crop and tillering stage of wheat crop followed by bromadiolone 0.005% wax cake at pod maturity stage of groundnut (ICBR 1:10.9) and milky stage of wheat crop (ICBR 1: 26.7) @ 10 g poison bait/live burrow.

iv. Application of bromadiolone 0.005% wax cake @ 10 g/bait station at an interval of three months in a year is recommended for effective management for different species of rodents viz., Rattus rattus, Rattus cutchicus and Bandicota bengalensis in poultry farm (ICBR 1: 62.3).

v. Two applications of bromadiolone 0.005% wax cake, first at the time of germination and second at pod formation stage (ICBR 1:52.08) or first application of zinc phosphide 2% poison bait at the time of germination and second application of bromadiolone 0.005% wax cake at pod formation stage (ICBR 1:22.71) each @ 10 g poison bait/live burrow are effective for rodent management in groundnut crop.

vi. Two applications of bromadiolone 0.005% wax cake, first at 30th day after sowing and second at 60th day after sowing (ICBR 1:39.40) or first application of zinc phosphide 2% poison bait at 30th day after sowing and second application of bromadiolone 0.005% wax cake at 60th day after sowing (ICBR 1:21.97) each @ 10 g poison bait/live burrow are effective for rodent management in cucumber crop.

vii. Four applications of bromadiolone 0.005% wax cake or cholecalciferol 0.075% wax block (when available in market) @10 g poison bait/live burrow or bait station at an interval of three months are recommended for rodent management in poultry farm.

viii. For effective and economic control of rodents in groundnut crop, three applications of bromadiolone 0.005% wax cake, first at the time of germination, second at pod formation and third at pod maturity stage (ICBR 1:21.75) or two applications of bromadiolone 0.005% wax cake (first at germination and second at pod maturity) and one application of zinc phosphide 2% poison bait at pod formation stage (ICBR 1:10.17) or two applications of bromadiolone 0.005% wax cake (first at germination and second at pod formation) and one application of zinc phosphide 2% poison bait at pod maturity stage (ICBR 1:9.84) are recommended. The poison bait should be used @ 10 gram per live burrow.

Continuous use of bromadiolone should be avoided. It is also advised that the dead rodents should be collected and destroyed to avoid second poisoning.

ix. Rodents in wheat crop can be effectively managed by three applications of bromadiolone 0.005% wax cake, first at germination, second at tillering and third at milky stage (ICBR 1:22.67) or two applications of bromadiolone, first at germination and then at milky stage and one application of zinc phosphide 2% poison bait at tillering (ICBR 1:12.78) or one application of zinc phosphide 2% poison bait at germination stage and two applications of bromadiolone at tillering and milky stage (ICBR 1:11.96) are recommended. The poison bait should be used @ 10 g/live burrow and dead rodents should be properly disposed off to avoid second poisoning.

Rodent Pests and their Management in NEH Region

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The North Eastern Hill States of India are full of green vegetation and bamboo forests which have become an integral part of 'the tribal life and its customs. These forests have various agro-ecological systems of which jhum cultivation is most important. Rats are causing heavy losses to agricultural crops in fields as well as in storage in this region. These pests have been found to create 'famine' like situation in Mizoram and Arunachal Pradesh during the time of bamboo flowering which is expected in the year 2007 in some states of this region.

Rodent Pest Species and their Infestation Pattern

The North Eastern Hill Region is quite rich in rodent fauna due various agro-climatic conditions and agro-ecological systems which provides variety of habitates for rodents. A total of 15 rodent species has been identified from this region belonging to various genera viz., Rattus, Bandicoot, Mus, Cannomys, Vandeleuria and Callosciurus etc. Earlier 25 rodent species have been identified from North Eastern Hill Region including Assam.

During survey of North Eastern states, Bandicota bengalensis has been recorded as a predominant species followed by Rattus nitidus nitidus, Mus musculus and Rattus rattus. In early years of study, Rattus nitidus nitidus and Rattus rattus were recorded as predominant species in Meghalaya in fields and residential areas, respectively. However, in recent years Bandicota bengalensis driven away these species and has attain the status of serious pest with its population reached to 94 percent in year 2000.

Studies on seasonal activities of rats revealed highest burrow density per hectare in the month of July and august and minimum during December - February. Rat activities exhibited an increasing trend from March onward and were maintained at higher level from March to November. The activity slowly increased from March when the crops and vegetation were available for food and reached to its peak from July to October at crop maturity stage.

Survey of rodents was conducted in all the states of NEH Region in different agro-ecosystems. Cumulative observation revealed that the rodent activities were highest in areas where animal and poultry farms existed (77.37%) The reasons may be due to availability of nutritious feed to them round the year. In cropped areas pineapple fields had the highest number of active burrows (44.25%) followed by upland rice cropped area and jhum fields. In non-cultivated areas, the pine forests had the highest number of active burrows while the wasteland areas also harbored 29.4% of active burrows.

Damage Assessment

Extensive studies on rodent damage to various crops were carried out in the states of NEH

Region. Damage by rats is inflicted in all the stages of crop growth, harvest, processing, transport and storage, the intensity varied with site and season. In these states, rats caused severe damage to paddy and maize which are the main food crops of this region.

Rice

Damage to lowland paddy was higher (4.6-16.8%) in comparison of upland paddy -9%). Rats damaged Paddy crop at different stages of growth. A severe damage to crop is caused between milky to maturity stage by cutting the tillers from the base. Incidence of damage was found to increase with the growth of crop and reached to maximum at maturity stage. Some early maturing varieties suffered 25-100% damage in lowland. Bandicota bengalensis and Rattus nitidus were found associated with paddy damage.

Maize

In maize crop damage started at grain formation stage reached to maximum at maturity stage. Damage to maize cobs ranged between 3.55-22.2%. In jhum cultivation in Mizoram maize cobs suffered a loss upto 24%.

Pineapple

Pineapple crop witnessed heavy losses due to rats and damage to ripen fruits was recorded upto 20.3% (range 2.6-20.3%). Apart from above crops. rats also damaged groundnut and some other vegetable crops but damage recorded was negligible. Mushroom was also damaged by rats by making holes in paddy straw blocks and destroying the mycelia growth resulting in total crop failure.

The stored maize, paddy and groundnut suffered heavy losses due to rodents in godown. Rats inflicted severe losses in residential premises, shops and stores etc. Predominant species associated with.damage in fields and field godowns were *Bandicota bengalensis*, *Rattus nitidus* nitidus and *Mus musculus*. While in urban area the damage was caused by *Bandicota bengalensis*, Rattus rattus and *Mus musculus*.

Evaluation of Rodenticides

Laboratory Evaluation

Various acute and chronic poisons were tested in laboratory against dominant species of rats. Among acute poisons zinc phosphide and barium carbonate, were tested against *Bandicota bengalensis, Rattus rattus* and *Rattus nitidis nitidus* and *Mus musculus*. Zinc phosphide (2% poison bait) was found most effective resulting 100% mortality within 24 hrs of ingestion followed by barium carbonate (70% mortality). Among anticoagulants, wax cakes of bromadiolone (0.005%), cholecalciferol (0-075%) and flocoumafen (0.005%) were evaluated against *B. bengalensis* in choice and no choice feeding tests. In no choice feeding bromadiolone provided 90%, 96.7% and 100% mortality with 1,2, and 3 days feeding respectively within 3 to 13 days. In choice feeding mortality was 86.66% and 93.33% in 2 and 3 days feeding trials. flocoumafen resulted 95% mortality in no choice test within 3-15 days after 1 and 2 days feeding and 90% and 95%

mortality in choice feeding of 2 and 3 days, respectively. cholecalciferol wax cake provided 70%; 90% and 100% kill in 1, 2 and 3 days feeding in no-choice test while 70% kill was recorded in 3 days feeding in choice test.

Poison baits of brodifacoum (0.005%) and warfarin (0.025%) resulted in 80% and 70% mortality of *B. bengalensis* (Singh et.al. 1994) . Racumin bait (Coumatetralyl) 0.0375 % prepared from racumin tracking powder, were also found very effective against *M. musculus* and *B. bengalensis* and resulted in 69.4 % and 100% mortality of *M. musculus* (within 4-8 days) and *B. bengalensis* (within 3-9 days), respectively. A new rodenticide difethialone was also tested against *B. bengalensis*, which resulted in 100% mortality in 4-15 days.

Field Evaluation

Acute rodenticide, celphos (Aluminium phosphide) @2 tab/burrow was found most effective and reduced the number of active burrows upto 1 00%.

Zinc phosphide bait (2%) in various compositions like rice based poison bait, wheat flour based poison bait, wax coated kneaded balls of wheat flour, animal membrane coated kneaded balls of wheat flour etc. were consumed between 33.2 - 67.0% and rats activity and was reduced by 64.05 - 94.45% while average consumption of bromadiolone wax blocks was 26.66% and resulted in 59.25-70.11 % reduction in rodent activity in terms of reduction of number of active burrows. Maximum reduction in active burrows was obtained by using zinc phosphide 2% poison bait followed by celphos @ 2 tab/burrow (94%). Racumin bait (0.0375%) was found effective in controlling the *B.bengalensis* in fields. It provided 84.09, 88.89 and 87.80 percent reduction of active burrows after 1,2, and 3 days treatment, respectively.

Several methods have been employed to combat rural, urban, and field rodent population. All suitable techniques and methods should be utilized in a compatible manner to manage the rodent population below economic threshold levels.

Mechanical Control

It includes the physical killing and trapping of rodents by various kinds of traps such as bandicoot, Sherman, mice, wonder and snap traps. Various kinds of local traps are also used in this region to kill the rats in field, and houses. In Mizoram, different traps such as vi-thang, chep-thang, hnuhtut, kawlper, mawngkhawng etc. are used by the local people in fields and were found very successful in controlling the rats. Rats trapped in live traps should not be freed at any other place otherwise they come back again to the same place. These captured rats should be dipped in water for few minutes to kill them. Extensive trapping has been proved to reduce the rodent population upto 50%. Selection of suitable attractive baits is very important for effective trapping.

Biological Control

Owls, cats, snakes, foxes, mongoose and kites are some of the major predators of rodents. In NEH region, cats have been seen to affect the rat density in villages. As a predator, although cats are useful in maintaining the natural ecological balances but do not prove to be a very effective

tool for rodent management.

Chemical control

Before starting the chemical control, survey of the area where control operations are to be conducted should be done to assess the intensity of infestation. Survey should be made by "alive or active burrow counting method". In this method, lst day all the burrows in the field are counted marked and closed with soil. On the 3rd day, these burrows are examined and if any burrow is open, which is an indication of the presence of rat in the burrow is called "alive or active burrows". Assessment of rodent damage both qualitative and quantitative should be worked out in fields and residential premises before starting the rodent control operations.

For getting effective results of chemical control operations, it is also important to know which bait material should be used for preparing poison baits. Locally available food grains should be used for preparing the poison bait. Mixing of additives like different vegetable oils, sugar etc. has been proved effective in increasing consumption of bait. Similarly, placement of poison bait is also an important factor, during control operations; Poison baits can be placed bitter is the his burrows or is bait containes/bait stations.

Several types of indigenous bait containers like hollow bamboo pieces, broken pitchers (earthen pots), coconut shells etc. can be used for this purpose. Bait should be placed at the places most frequently visited by the rats and in their runways. The habitats and movement of rodents also must be kept in mind before placing the baits, this will not only increase the efficiency of consumption of poison bait but also reduces the cost of baiting in the rodent control operations. The following operational calendar has been recommended for the successful management of the rodents.

Some important considerations

- Use of zinc phosphide should be avoided in residential premises.
- Use of aluminium phosphide should be done in the supervision of trained personnel. Fumigation should not be done in residential areas
- For the better results, the rodent control operations should be undertaken in the larger area involving maximum peoples of the area.
- If burrows are not visible in fields, rodenticides should be kept on the bunds by using bait station. Placement of bait should be done in a way to cover maximum possible area.
- For the better results, the rodent control operations should be undertaken in the larger area involving maximum peoples of the area.
- If burrows are not visible in fields, rodenticides should be kept on the bunds by using bait station.
- Placement of bait should be done in a way to cover maximum possible area.

BAMBOO FLOWERING AND RODENT OUT-BREAK IN NORTH EASTERN HILL REGION OF INDIA

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The North Eastern states of India are abundant with bamboo forests and bamboo is an integral part of tribal people's life. Mass bamboo flowering in Mizoram and Arunachal Pradesh is known to be the cause of the famine due to the sudden out break of rodent population causing heavy to very heavy losses to field crops, stored grains and other articles of daily use. So far, 15 rodent species had been identified from this region. The flowering cycle of Bambusa tulda, Dendrocalamus logipathus and Melocanna bambusoides has been reported as the cause of the famines known as 'Mautam' and 'Thingtam' in Mizoram. Rattus rattus and Rattus nitidus are the most destructive and reported to be responsible for the famines. The prolific breeding of rats due to high nutritive value of bamboo seeds, reduction in the cannibalism due to the availability of plenty food during the bamboo flowering and change in the ecological conditions might be the probable reasons for the rodent out break. Next bamboo flowering in the region is expected in the year 2007 and to combat the expected rodent menace during bamboo flowering short and long term strategies must be adopted.

The states of North East (NE) India have hill ranges of varying altitude possessing unique agro-climatic conditions and physiography. This region has most difficult hill terrain having deep forest of which major portion is covered by different kinds of bamboo. With diverse agro-climatic conditions, the region provides a variety of habitats to different rodent species. Fifteen rodent species have already been identified from this region. The bamboo, plays a significant role in the socio-economic life of rural people of NE region. However, bamboo flowering, an event of rare occurrence, has been reported to be associated with distress and famine in various parts of the region.

Bamboo flowering and rodent outbreak

Outbreak and plague of rodents are recorded in religious, historical and scientific literature. Mass bamboo flowering in Mizoram and Arunachal Pradesh is well known for causing famine. The phenomenon of fluctuations in mammalian population, especially in rodents, has been recognized all over the world. In Mizoram two types of famines i.e. Mautam (brought about the flowering of bamboo "Mao" (Melocanna bambusoides) and Thingtam (associated with the flowering of two species of bamboo viz. "Rawnal" (Dendrocalamus longispathus) and "Rawthing" (Bambusa tulda) are recognised. Out of these "Mautam" is said to be much more severe than "Thingtam". M. bambusoides which flowers in 48 ± 2 years cycle is the commonest bamboo over these hills and they flower all at the same time and the rats increases suddenly over extensive area causing famine. While the flowering of B. tulda and D. longispathus during 1924 - 1928 stretched over a period of 4 -5 years causing "Thingtam" with gradual buildup of rat population inducing more of scarcity

than famine (Pillai, 1980). The period between two, famine is said to be generally 50 years. First record of "Mautam" was in 1864 when rats multiplied spontaneously and hundreds of Lushais were killed as a result of famine (Parry, 1931). Pearson (1930) also reported a similar outbreak of rats associated with bamboo flowering in 1911-1912. The gap between "Mautam" and "Thingtam" is 18 and 30 years approximately. The flowering of different bamboo species, period and occurrence of flowering are shown in table 1.

Table 1. Bamboo flowering, period and year in Mizoram

Bamboo in flower	Period	Year
B. tulda; D. longispathus	Thingtam	1880-1884
Melocanna bambusoides	Mautam	1910-1912
B. tulda; D. longispathus	Thingtam	1928-1929
Melocanna bambusoides	Mautam	1958-1959
B. tulda; D. longispathus	Thingtam	1976-1977
Melocanna bambusoides	Mautam	2007*

*Expected year of flowering of Melocanna sp.

During recent outbreak of rodents in 1958-59, tremendous losses were reported from Mizoram. The rats in an area of 1000 square miles developed into a "Plague" in Mizoram and ate up food stock and standing crop. The rodent outbreak was further spread in neighbouring area of Cachar and Tripura where about 1000 acres of green fields were devastated resulting into famine. Paddy crops were totally destroyed after which rats ate chilli, tobacco, ginger etc. Simultaneously all the crops near Indian border were eaten up where Indians were settled on Myanmar side, for generations. Similar records of outbreak in 1920-1921 and 1929-1930 induced by the flowering of bamboo are available from Garo Hills and Nagaland also.

In East Kameng District of Arunachal Pradesh, bamboo flowering followed by increase in rodent population was reported in 1991. The rat menace comes in cycles and it appeared in that area after 20 years. The tribals take it a ominous sign of famine when the bamboo starts flowering (Anon. 1991). In Arunachal Pradesh out of two types of bamboo i.e. "Bijali" and "Hitae" or "Kako", Bijali, which flowers at an interval of 18-20 years, is most suitable for rat's inhabitation and their food. The Hitae flowers at an interval of 45-50 years and is not preferred by rats (Gupta, 1980). Recently, the reports of bamboo flowering have sent an alarm in the states of NE Region. Massive flowering in 1998 winters and a corresponding increase in rat population was reported to pose a threat to large scale famine in Tamenglong, Churachandpur and Ukhrul District of Manipur. Earlier this phenomenon was reported in 1954-1955 in Manipur when state witnessed a famine. North Cachar District of Assam is also supposed to witness the bamboo flowering by the year

2000, which was earlier reported in 1957. In this area 3 kinds of bamboo, Jati, Muli and Pessa have already started to bloom in Langtin and Hatikali areas. Mizoram state which faced a famine in 1958-1959 is expecting the mass bamboo flowering in 2007 A.D.

Correlation between bamboo flowering and increase in rodent population

Increase in rodent population associated with bamboo flowering has been reported in other countries also. Outbreaks in the population of voles following the flowering of Sasa ichizuchiana have also been reported from at-Mount Tsurug, Shikoku. Similarly outbreak of Microtus montebelli in mountainous area of Kansari and Chugoku in recent years following the flowering of Sasa sp. in 1963, 1967, 1969 and Pleioblustus sp. in 1970 have been reported. The factors, which induced the outbreak, are not clearly known. Attempts have been made to establish the correlation between bamboo flowering and rodent outbreak. However, some report suggested that bamboo flowering does not play any significant role in rodent outbreak. Increase in rodent population during bamboo flowering may be due to following factors

Congregation due to migration

Enormous seed production during bamboo flowering increases the food availability for rodents. During this period, the neighbouring rodent population seems to migrate to the site, where plenty of food is available. The increase in the amount of food available was probably the most common proximal cause of increase in rat population. Hence, the spontaneous increase in rodent population may be because of availability of excess food. An outbreak of rodents associated with flowering of Brazilian bamboo, having a flowering cycles of about 30 years, was reported. However, the bamboo does not flower and seed simultaneously but the process lasts about 5 years. The rats and mice increase extra ordinarily in numbers due to sudden and constantly increasing supply of nourishing food for a period of 5 years. When this source of food is finished, the rats migrate to the crops, plantations and houses consuming everything.

Prolific breeding due to high nutritive value of bamboo seeds

It is also possible that the high nutritive value of bamboo seeds helps in prolific breeding. In an effort to find a relationship between bamboo flowering and rodent population, Mahadevan, et. al., (1961) observed that the reproductive behaviour of experimental rats, fed on bamboo flower, had no effect on their reproductive behaviour. According to Janzen (1976) small rodents are likely to have a powerful reproductive response to the abundant food supply during mast (synchronized production of seed at long intervals by a population of plants) seeding of bamboo which is true for Rattus, a genus with native species associated with Indian and Asian mast seeding bamboo. The bamboo seeds have a good nutritive value. When the seeds of *Bambusa arunidinacea* and *Dendrocalamus strictus* and paddy (as check) were fed to *Rattus nitidus* and *Rattus norvegicus* (Albino) it was observed that bamboo seeds had no obvious effect on breeding of experimental rats.

Change in environmental and ecological condition

Population of rodents may greatly depend on environmental factors and probably favourable

environmental changes bring about rapid multiplication of rats. It is evident in case of Lemming which exhibit a cyclic population booms every 4 years. Linked population explosion to the local weather. Data obtained for rainfall from Lushaicherra showed that higher amount of precipitation was recorded during 1976 than the previous years, which might be one of the causes of rodent outbreak. It is possible that rats had good chance of multiplying in fields left idle in the previous years due to the failure of the monsoon. Water closes the cracks in the earth as a result of which many rats are normally killed. He was also of the view that the major part of phenomenon was played by a species of red-tick parasite, which might have spread an epidemic, bringing the population down. These ticks breed in the grass and in famine years, following failure of monsoon, there is great diminution of grasses. The decreased humidity also may have a detrimental effect on the tick population and these tick parasites, which possibly keep a check on rat population in normal years fail to check the rat population. The increased precipitation due to heavy rainfall could alter the vegetation creating a favourable habitat and cover from the predators. The human interference with ecosystem may also contribute to this problem, as the predator population is not in balance with that of prey. Due to mass bamboo flowering there is sudden change in the entire ecosystems of forest, which help rodents in many ways. Increase in vegetation may also help rodents in better survival. Entire ecosystem may play a vital role in such a phenomenon.

Rodent problem in NEH region especially at the time of bamboo flowering has certainly assumed alarming proportions. Though the factors which induced the outbreak of rodents are not clearly known, even then this phenomenon cannot be outrightly rejected but more studies on the biology of rodents including ecological aspects should be carried out to understand the problem. As next famine is expected in the year 2007, all the possible long term and short-term measures should be taken up to deal with the problem.

Following strategies are suggested to be taken up to deal with the problem of expected rodent out-break.

1. Regular survey of jhum and bamboo flowering areas should be planned on long term basis to monitor the rodent pest incidence to help in planning and organizing rodent control campaigns.

2. Training programmes should be organized for the plant protection officials, extension workers, village council members, NGOs, farmers etc. through various agencies such as National Plant Protection and Training Institute, Hyderabad, Department of Plant Protection and Quarantine (Govt. of India), Faridabad, Project Coordinator, AICRP on Rodent control and Unit of AICRP on Rodent Control, ICAR Research Complex, Umiam, Meghalaya.

3. Farmers and other inhabitants should be made aware of rodent problems by conducting regular training programmes and field demonstrations. Use of mass media, audio-visual aids, posters, pamphlets etc. should be initiated by state government to educate the people of problematic areas regarding rodent problems and strategies to combat the expected rodent menace in year 2007.

4. State governments should have a proper coordination with all agencies engaged in rodent control research to work out the strategies to meet the challenge of expected outbreak.

EFFORTS OF GOVERNMENT OF INDIA IN NORTH-EASTERN STATES IN CONTEXT WITH RODENT SITUATION AND BAMBOO FLOWERING

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1. Background :

The North-eastern region comprising the States of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura accounts for 7.7 per cent of area and 4.04 per cent of country's population. The economy of the region is primarily agricultural with majority of the people still practicing `jhum' or shifting cultivation. Natural bamboo forest and other natural vegetation normally surround the jhum fields. These are favorite habitats fr rodents. Bamboos of several varieties are present, out of which 7to 8 are reported to be associated with sporadic rodent outbreak. The past instances of rodent upsurges associated with the bamboo flowering in this region are as given below :

Period	Year
Thingtam*	1880-84
Mautam**	1910-12
Thingtam	1928-29
Mautam	1958-59
Thingtam	1976-77

* Thingtam occurs at an interval of 45 to 50 years.

** Mautam occurs at an interval of 48 to 50 years.

It is anticipated that another such upsurge will occur during 2007. This presumption is primarily due to the regular periodicity of the rodent outbreaks felt by this region. CAR forewarned that another such upsurge is likely to occut during 2007.

The farmers in the North-eastern region usually attend rodent control when the crop is matured and also after the harvest. The methods adopted include netting, trapping, digging of burrows and zinc phosphide baiting. Adequate care is to be taken to use rodenticides since tats are eaten by the villagers and considered as delicacy.

The on-going reports of sporadic bamboo flowering from Arunachal Pradesh, Manipur,

Mizoram, Nagaland and Tripura are precursor to gregarious bamboo flowering cycle. The gregarious bamboo flowering gives rise to enormous quantity of bamboo seeds near the bamboo clumps. It is believed that the gregarious flowering is synchronized with sudden increase of rodent population, thereby causing tamine. There are reports that these famines also caused human deaths.

The upsurge in rodent populationcan be attributed to the interplay of ecological factors, which influence the rat population at the time when gregarious flowering occuts. The short generation time and high turnover rate of rodent reproduction coupled with mass feeding of bamboos are considered major factors of a rodent outbreak. Spontaneous increase in rodent population is because of availability of excess food, the high nutritive vaule of bamboo seeds, resulting in r-pattern of rodent breeding as per some collaborative scientific views. The reduction is cannibalism due to plenty o food and absence of natural predators help in greater survival of juvenile population.

2. Major Rodent Species

In North Eastern Region, sixteen species of rodents were recorded belonging to 6 genera. Among them *Bandicota bengalensis* is reported as a predominant species (31.57% of the total collection), followed by *Rattus nitidus* (24.51%), the former dominating in Meghalaya and Manipur, while the latter in Arunachal Pradesh, Meghalaya and Sikkim. *Rattus rattus* constituted 14.3% and *Mus musculus* 16.9% in houses. The Norway rat, *Rattus norvegicus* is observed in the collections from Meghalaya (5.15%) and Mizoram (4.73%).

The following are the other rodent species reported (8.17% of total collections): *Rattus rattus khyensis* (in Mizoram), the Bower's rat, *Rattus bowersi* (in Meghalaya and Mizoram), Rattus rattus tistae (in Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Sikkim and Tripura), White bellied rat, *Niviventer niviventer* (in Meghalaya), the Indian field mouse, *Mus booduga* (in Mizoram and Sikkim).

Based on the above informationit is apparent that only4 rodent species are of economic importance in this region. It may also be possible that the species identificationis often difficult, especially among *Rattus* genera. As a result, Rattus rattus brunneusculus, *Rattus rattus tistae, Rattus rattus khyensis, Niviventer niviventer* are often could be nisidentified.

As per theavailable information generated through ICAR researchproject in the NE States, the rodent related looses account to 4.35 to 12.48% to rice, 4.71 to 8.53% to pine apple and 7.9 to 9.14% to maize cobs. This information is restricted to the States of Meghalaya and Mizoram only.

3. Possible control measures :

3.1. Trapping : The indigenously available bambootraps in the region are very effective in normal situations. Different types of bamboo traps are available in the region, which give instant kill to the trapped rodents. Employing these traps @ 25 per hectare on the periphery of the jhum/WRC fields will tackle immigrating rodents during establishment period of the crop. Trap barrier system can be adopted by placing these traps on the periphery of jhum fields at periodic intervals after demarcatingthe jhum with bamboo pegs Bio-control :

The populations of spotted owlets or barn owls inthe Region are not adequate for bringing significantresults as bio-agents. Mostly these owls are humted and removed from their natural environs. Efforts are required to conserve these owls. Owl perches are not required in the jhum fields since adjoining forest area act as perching sites for these raptor bird species.

3.2. Bounty payment : It is a practice that incentive system is used to kill more number of rats in any area. Under this system an amount of Re. 1/- or even more will be paid to individuals on production of rat tails at earmarked places. The genesis of this is more number o rats will be killed by the farming community due to the incentive. However, globally it is acknowledged such bounty system resulted in stimulating rodent reproduction in those areas; thereby increasing the rodent populations in these areas. However, it may be affective when the rodent problem is very serious and implemented in unit time and unit area basis.

3.3. Smoking the borrows : The second meeting ofthe Expert Committee on Rodent Control during April, 2002 felt that fumigation of rodent burrows in the NE States with smoke generator developed by the Acharya N.G. Ranga Agricultural University, Agricultural Research Station, Maruteru, West Godavari district, Andhra Pradesh may be appropriate. However, systematic evaluation of this is required in his region by either respective Agriculture Departments or ICAR centers in the Region.

3.4. Chemical control : As far as possible chemicalapplication for treating rodent populations should be restricted to bare minimum in NE region. Rodents are normally a delicacy in majority areas of the Region. The chemicals to be used are given in Technical approach.

4. Efforts by Central and State Governments:

4.1. Visit of ordent experts : Based on the ICAR forewarning, a central team of rodent experts visited North-Eastern States during May, 1998 for making on-the-spot assessment of rodent situation and to organize demonstrations on rodent pest management. The team recommended precise survey ofthe sporadic flowering areas, surveillance of rodent incidence in the jhum fields, creating awareness amongst the residents on the probable rodent problem in the region due to commencement of bamboo flowering, encouraging use of indigenous bamboo traps and rodent pest management techniques by using safer anticoagulants.

4.2. Expert Committee on Rodent Control : Expert Committee on Rodent Control of Government of India met in January, 2000 and identified major `Action Points' as well as `Action Plans' on rodent pest management to be implemented by the North Eaxtern States with special reference to i) identifying sporadic bamboo flowering localities, b) monitoring the rodent incidence in these localities, c) creating awareness among the farming community through suitable media and publicity, d) human resource development among departmental officers, and e) rodent management measures with a mix of using local bamboo traps and safer anticoagulants with suitable precautions in their usage. Subsequently the reconstituted Expert Committee met during April, 2002 and reviewed the existing situation. The committee felt the need of closer monitoring of rodent incidence in these States.

4.3. Action by North-Eastern States : Reports were received from Arunachal Pradesh, Manipur, Mizoram and Nagaland on rodent depredations coinciding with bamboo flowering during the year 1999-2000. Although some of the North Eastern States intiated some rodent control measures through bounty payments and through usage of rodenticides, they expressed the problem of proper technical approach as well as financial resources to take up various activities like joint survey of bamboo flowering areas and regular monitoring of rodent situation inthese areas etc. and requested for central assistance. Therefore, suitable guidelines on technical approach were sent by the Union Department of Agriculture & Cooperation to the North-Eastern States.

4.4. Macro Management in Agriculture : Looking at the financial requirement for initiation of various actions by the concerned States to prevent possible rodent upsurge and request of the concerned NE States, the committee recommended that the affected States may includethe component of rodent control under Marco management scheme of Department of Agriculture and Cooperation. TheStates of Manupur, Mizoram and Nagaland included this component under the Macro management mode and requested for additional assistance. The P & P Division of the DAC is requested to consider the request of these States favourably.

5. Technical Approach For The Region

The Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India worked out the technical approach for various action points for rodent management in the region in consultation with concerned technical.

The Common Barn owl - An Eco-friendly Bio-control agent

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In general, five methods, vize, cultural Physical mechnical, biological and chemical can manage any pest of a crop. Of these, biological control of pests is one of the Eco-friendly methods and is widely recommended by the pest managers of today, throughout the world. The beneficial role of the common barn own (*Tyto alba stertens*) in containing the rodent pest of agricultural importance in Cauvery delta has been reported.

Owls, in general, are soft plumaged, short tailed, bigheaded raptors with large eyes directed forwards and surrounded by a facial disc. They are mainly nocturnal or crespuscular in habit, and 134 living species are at present known from all over the world.

Of these, the barn own can easily be recognized by its heart shaped facial disk, dark brown eyes and absence of eary tufts. The female barn owls ($\overline{X}$=424.5 g) are bigger than males ($\overline{X}$= 381.6 g). It has got an acute sense of hearing and can locate its prey even in absolute darkness. The barn own swallows its prey as a whole or at times the head of the prey alone. The fleshy portions of the prey eaten are digested and the undigested fur and bones cast up and regugitated by the barn owl on the subsequent day in the form of a pellet.

The barn owls are ubiquitous in distribution and in fact, it is one of the most widely distributed of all birds. As for as Cauvery delta is concerned barn owls primarily inhabit man-made structures, hunting over agricultural lands, human habitations and groves for rodent pests and shrews.

Identification of Barn owl nests/roosts

The indirect signs of barn owls can be used for this purpose. They are the regurgitated pellets (contain the undigested fur and bones of the prey eaten), prey remains in the roosting/ nesting sites, milky white dropping on the floor and on the walls and food begging calls of the nestling after sunset.

Nesting and roosting sites

Barn owls do not construct a nest, however, occasinally they use their own pellets as a cradle for egg laying and rearing nestling. Our observations in Nagappattinam district, Tamil Nadu revealed that the inner side of the temple towers, gaps present in the status aroung the temple towers and sanctum sanctorum, unused rooms and barns in the temples, dilapidated buildings, big tree holes and branches/crowns of trees with dense foliage are the nesting/roosting sites of barn owls. Almost all the nests were found in dark places. However, a few nests were located outside the temple towers that too in sunlight. Most of the nests were found at a height of 9-12m. The results of the habitat evaluation indicated that rural areas had more number of nest (18) than urban

areas (07). This may be due to the availability of agricultural land in large areas.

Diet in Nature

The predatry pressure of barn owls over different prey spectrun was studied by an indirect method viz., the regurgitated pellet analysis, which is a reliable technique than other techniques as far as owls are concerned and particularly for barn owls. The collected pellets were analysed, individually by using 8% NaOH. The contents of the analysed pellets were utilized for prey species identification upto species.

Anaysis of 4574 pellets for a period of 31 months revealed that the rodents, insectivorous small mammals (Grey musk shrews), amphibians, birds and insects constituted the diet. Among the prey items, the rodent pests such as *Bandicota bengalensis* (31.97%) *Millardia meltada* (24.70%), *Mus booduga* (4.51%) *Tatera indica* (1.42%) *Rattus rattus* (4.90%) with unidenitified rodent species accounted for 77.68% of the total prey intake. The remaining prey composition were shared by *Suncus murinus* (10.12%) amphibians (11.44%) birds (0.02%) and insects (0.34%)

Interstingly, most of the pellets had more than one prey item of species and they ranged form one to a maximum of six indicating that the barn owls consumed more than one rodent/day under wild conditions.

The total biomass (g) and proportions of small mammalian prey of barn owl for 31 months were estimated by using mean body weight of respective species. The results disclosed that the barn owls have consumed 4,19,523.52 g of prey comprising six species of small mammals. Of these, the *B. bengalensis* accounted for 1,90,859.55 g, which is 45.49 per cent of the total small mammalian prey composition.

Food in captivity

The daily food requirement of adult and sub-adult barn owls in terms of both frequency and biomass were studied under captive conditions. Individually caged, for healthy adults (X=382.50g ; range 410-420g) were empolyed for this study. Different species of rodent pests viz., *Bandicota bengalensis, Millardia meltada, Tatera indica* and *Rattus rattus* weighing more than 75 g in body weight were offered around 18 hrs everday, to every caged individual. In case of non-availability of rodents weighing more than 75 , two to six animals weighing in all 75 g or a little above were offered. *B. bengalensis* was consumed in greater quantity (in terms of biomass) by captive adult (70.85+20.03g) and by sub-adult barn owls (78.41±20.37 g) compared to other species of rodents offered. The mean (all species of rodents) number of prey and prey weight consumed by the adult barn owl/day was 1.58 and 64.62±17.14g, respectively which is equivalent to 16.89% adult barn owls body weight. Similarly, the mean number of total prey and prey weight consumed/day by the sub-adults was 1.56 and 68.01+15.49g respecitvely or 16.43% of the sub-adults body weight. The range of pellets regurgitated/day by the adults was 1-3 (overall) while it was 1-2 (overall) for sub-adult barn owls with a mean time taken for regurgitation/day was 14.15 hrs for both adult and sub-adult barn owls. The monthly-extrapolated prey requirements of one adult and one sub-adult barn owl in terms of number of prey items were 47 each while the annual requirements were 577 for adults and 569 for sub-adults. The extrapolated monthly and annual

prey requirements in terms of biomass were 1,939g and 23,586 g for one adult barn owl ; and 2,040 g and 24,824 g for one sub-adult barn owl, respectively. The result of the present study vividly point out that the barn owl can be a good predator of rodents in nature.

It is apparent from the above results, in terms of both frequency and biomass the barn owl have ingested greatly, the predominant vertebrate pest of Cauvery delta viz., *B. Begalensis*. Beside, the other rodent pest are also taken by the barn owls to a significant extent and hence we can very well conclude that this bird is an effective predator of rodent pests of both agricultural and medical imporance.

Nesting and productivity

Barn owls are well known for their great reproductive abilities. In our observation, the clutch size varied from 3 to 8 and the brood size from 2 to 7 nestling. Eggs were incubated for a period of 30 to 35 days. The nestling were voracious eaters of rodent pests and they used to engulf the entire prey. Becuase of this feeding activity the nestlings grow very quickly and fledge between 70 and 75 days. According to an estimation a barn owl family comprising parents and six youngones consumed nearly 700 to 800 rodents in about three months of time. The overall nestling success was found to be 50%.

Artificial nest Box

As soon as the value of barn owl in checking the rodent pests in recognized, efforts were made to conserve and propagate the barn owls in a portion of Nagappattinam district, Tamil Nadu. As a part of conservation and propagation strategy of barn owls, an artificial nest box was designed with the following dimensions i.e., 36x18x21 inches.

Forty nest boxes were installed in the places where poor quality of natural nesting sites were observed and all other possible man-made structures and trees. The height of the installed nest boxes ranged from 3 to 10 m above ground level. The mean percentage of utilization of barn owl for nesting and roosting was found to be high in the boxes installed near to human habitations (45.2%) followed by agricultural lands (41.8%) and groves (16.3%). The barn owls used maximum number of boxes during peak breeding season (Novemver to April) than the non-breeding season. The overall mean nst box utilization by barn owl for nesting and roosting was 40.9% over a period of 17 months. It is worthmentioning that once a nest box was used by barn owls they continued to nest there in subsequetn seasons showing considerable site fidelity. Thus, it is suggested that the provision of nest boxes for barn owls in the man-made structures and trees near to agricultural lands where the prey is abundant, would be a feasible strategy for the effective conservation and propagation of barn owls.

Artificial perches

The common barn owl requires a perching place to sit and observe the prey. In this method the vertebrate pests are checked to certain extent by biological means. Perching poles of "T" shape (3 m in height with a 3/4-m or 2 feet cross bar-whose diameter must be 2 inches) are prepared for the avain predators especially for barn owls (*Tyto alba stertens*). They are to be

planted (10 m off from the bunds where the activities of rodents pests are high) in the crop fields in order to provide more accessibility for such predators to capture and gobble the rodent pests. The distance between two poles may be maintained between 10 and 15 m. The results revealed that the 3 m high perching poles were utilized by the barn owls to the tune of 70% during Kuruvai season and 60% during Thaladi season.

Further, the diurnal insectivorous birds like black drongo (*Dicrurus adsimilis*), small green Bee-eater (*Meropes orientalis*), white-breasted kingfisher (*Halcyon smymensis*) and blue Jay or Indian roller (*Coracias benghalensis*) also used the perching poles. Of them, the black drongos utilized the poles more frequently than the other insectivorous birds. Thus, the plantation of 3 m high perching poles in the rice fields would not only help the farmers to contain the rodent pests during night hours, but also the insect pests during day time, to certain extent it has been concluded that the density of rodent pests and their depredation to rice crop was found to be minimum when compared to control plots in both seasons. They have also outlined the importance of studying the utilization of these perches by avain predators on other important crop fields and fallow lands as well.

ROLE OF EXTENSION EDUCATION AND TRAINING IN RODENT MANAGEMENT

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Rodents are a real threat to out agriculture and health. Though, sufficient and cost effective technologies have been evolved over a period to contain the rodent means, yet these have not yet uniformly percolated to the end users. These could be several reasons for this. These are being discussed below.

EDUCATION

This is the field where we are lacking the most. By educating different category of people we can increase their knowledge on rodent control. Besides, this, there attitudes can also be moulded. Religious taboos are measure constraints in our society which hinder even initiation of rodent management programmes. These taboos are prevalent throughout the country in one form or the other. Therefore, proper education at proper time that too through proper media is very important.

In Rajasthan, at the time of sowing of crops, the farmers usually put 2-3 handfuls of seeds in the name of rodents and birds. This is not because they are not aware of the problems, but because lack of knowledge rodent management technology. Hence, knowledge on the technology attains major importance, but there are people who do not want to kill rodent at any cost. Therefore, their attitudes need to be changed. However, it is said "You can teach a young parakeet but not an adult one". Similarly, to change the attitudes of adults who play a key role in the decision making process at least in respect of rodent control, is a herculean task. Therefore, if we infuse in school going children the idea that rodents are perilous creatures and need to be dealt with tactfully, probably we may succeed in building a solid base of social consciousness which will encourage the people to hate the damaging rodents and to take suitade measures to manage them.

Rodents start their damaging activities in agricultural fields when a farmer has pooled all his resources in collecting the necessary inputs like seed, fertilizer, etc. Thus, rodents while damaging all his agricultural components also waste his labours and create famine like conditions.

ROLE OF MEDIA IN EDUCATION

With the steady increase in literacy, the role of print media has assumed alarming importance. Newspapers and magazines have deep oted approach in rural sectors, Therefore regular gearing upon rodent management technology through print media will help to a large extent in broadening the horizon of farmers thinking on rodent problems.

At present, "Radio" is the only mass media in the rural sector. Through this aid, awareness and interest of the masses can be created. However, the things which are heard can hardly be retained in the memory for a longer period. Therefore, the role of television assumes greater

importance. Out of any five senses, at least two viz., vision and hearing, are in the grip of television. Hence, memories linger for a longer duration through TV.

If the enormous losses caused by rodents are brought to the notice of all, at least a thinking against rodents can be generated. After development of such thinking, programmes incorporating management technology may be telecasted. Even the farmers who have adopted or used the management technology and have benefited from it may be invited to the studios and their experiences may be share by all.

Besides this, education of extension workers needs to be intensified on a priority basis. From the technocrat to field level staff may be educated about rodents, if necessary.

TRAINING

Since rodent management technologies are easy to operate and are quick result oriented and socially accepted economic viable these can be translated into practice on farmers fields. But, for proper dissemination of knowledge on this aspect, all the strata dealing with extension education need to be invariably trained. This training may be divided into :

Apex Level Training : This training is to be imparted to the Directors of Agriculture. The contents of the course or methodology may emphasise on management of transfer of technology, the type of training required for the lower strata, man-management, molding the attitude and behaviour of the people towards rodent control; and on effective communication.

Besides these, inter-personnel, and organizational problems in translating the technology need to be resolved. Further, procurement of inputs like rodenticides, baits etc. should also be considered in this training. Last, but not the least, the coverage of Government lands, Common Property Resources, Railway tracks, road sides, etc. should receive the highest priority for rodent control work, because these are the real breeding grounds of rodents.

Middle Level Training : This may be imparted to personnel from ICAR Institutes, Agricultural Universities etc. Here knowledgeable persons may be suitably trained in the technology. The duration of the training may be of one week. However, a refresher course should also be conducted once in a two year period.

Field Level Training : The present T&V system is quite effective. Therefore, all the training programmes for Subject Matter Specialist to farmers etc. may invariably include a package of rodent management technology. Since rodent management is a skill oriented training more emphasis is to be laid on practices, i.e., preparation of baits, laying of baits, etc.

Training Among Farmers : National Social service (NSS) squods, Nehru Yuvak Kendras, farmers' clubs, Yuvak Dals, and Mahila Mandals are working among farmers. Within these organizations "Rodent Control Squads" should be formed. The squads may be given vigorous training in rodent management techniques, and on the availability of rodenticides and baits, etc. When these squads are fully prepared, the media may be utilized to popularize the rodent control campaigns on community basis.

Like "Van-Mahotsava" a rodent control we may be celebrated before the sowing of crops i.e. in May-June or in October-November. Attractive and easily memorable slogans like "Kill a rat a day keep hunger away" or "A grain saved is a grain produced" or "Rodents are enemies of your food, fodder and health - keep them away" should be popularized.

Present status of knowledge and Level of Training Programme :

A probe into data on training programmes especially their utility, converge of course and training efficiency index on rodent control reflected that the scores over 70 per cent to 94 per cent.

Thus, the requirement of rodent control technologies for above mentioned areas is highly justified as the utility of the programme varied from 72 to 93 per cent and coverage of the course (present knowledge on rodent control) varied from 71 to 94 per cent, both of which are very satisfactory figures. Besides the training efficiency indices fluctuated from 74 to 90 per cent, which speak commendable quality of performance of the trainers and the knowledge disseminated. So, there is no dearth of knowledge on rodent control, but it is certainly not finding its way to the end-users, i.e., the actual translation of the technology at the farmers fields is lagging behind. This needs to be improved to the desired levels all through the country.

PRIORITIES OF RESEARCH ON RODENT MANAGEMENT

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Rodent pests have been instrumental in causing severe losses to our food and fodder production, fruit and forestry plantations, besides threatening the human and livestock health. AICRP on Rodent Control, during the course of its operation, has made significant advancements in major priorities of applied rodentology. One of the major strengths of the Project has been a clearer understanding of the rodent pest status under various agroecosystem of the country. On the base of ecological, ethological and biological understanding of these pests several control techniques have been evaluated. The project has made steady progress in evolving management schedules for majesty of crops/cropping system. The technology developed is been regularly tested and refined at farmers' fields under Social Engineering Activity on Rodent Control.

In the era of pest management, one has to take a holistic approach for devising an effective and economic management technology which is environmentally safer also. So far our technology is solely dependent on use of toxic chemicals like rodenticides. With the evolution of second generation anticoagulants the technology has undergone a revolution because these rodenticides are quick in action (like acute poisons) and are quite safer to non target organisms. Inspite of these developments our efforts should be minimize the bad chemical toxicants in the environment. For this search for safer and nonlethal methods needs to be explored so as to evolve a real Integrated management of pest rodents. Infact the pattern of infestation, behaviour and ecobiological parameters for rodent pests are entirely different from that of insect pests. Accordingly our management strategy is also to be tuned to suit the targets (i.e. rodents), non targets (biotic agents) and the clientele (endusers). Some of the research priorities on rodent management are briefed as under :

Monitoring the rodent bio-diversity in different agro ecosystems

Vast areas of cultivable land in the country is witnessing a major shift in land-use pattern, which is resulting in invasion of newer rodent pest complex by replacing the endemic fauna. For example, in arid western Rajasthan, advent of Indira Gandhi Canal has changed the overall cropping pattern, which threatens the existence of xeric rodent fauna and invasion of more destructive mesic species. Similarly the coastal zones are experiencing introduction of large scale oil palm plantation. In NEH region, next cycle of bamboo flowering is expected by 2005-2007 A.D. for which we have to be forearmed for any famine like situation due to rodent outbreaks. Moreover long term monitoring of rodent pest populations, with special reference to high altitude horticultural crops and dryland agriculture needs to be taken up in line with locust surveys.

Ecological takeover among sympatric rodents

Any control operation or ecological stress tend to eliminate the predominant rodent species

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first, leading to upsurge of codominant or subdominant species of the pest complex. So far, we do not have any quantified information on this aspect of ecological takeover. Such studies may be helpful in planning strategies for IPM.

Island ecosystems

There is no concrete information on rodent fauna of island ecosystem, where Government of India has initiated growing of plantation crops like coconut and oilpalms. These crops have entirely different gravity of rodent problem, thus require special strategies for the rodent management. In Lakshadweep islands, rodents have been exposed to warfarin treatments on a large scale for more than a decade. This island, thus, may be a suitable site for monitoring the existence of warfarin resistant strains of rodents. Introduction of barn owls, a predator of rodents, may also be investigated for biological control of the arboreal rodents infesting the plantation crops.

Evaluation of chemosterilants, attractants and repellents

Such chemicals also require in depth investigation, as a means of non lethal approach for rodent management. Our colleagues have investigated potential of alpha chlorohydrin as male sterilant against B. bengalensis. Similarly urine and sebum of conspecific rodents of some species have been found to act as attractant/feeding stimulants. Some plant products with similar characteristics may also be investigated.

Biological control

Several predators and parasites are listed in literature for biological control of rodents, but none of them proved their worth in practicality. During last 5-6 years, potential of barn owls for predating upon field rodents have been investigated. Such predatory mammals, birds, reptiles etc. should be adequately studied with a view to work out their role in effective control of various field rodents.

Breeding centers

Most of the government owned lands like, wildlife sanctuaries, national parks, road sides, railway tracks and other common property resources act as ideal breeding loci for rodent pests. It is, therefore, essential that concerned authorities develop a system of checking the rodent population growth in their respective territories.

Studies on rodent taxonomy

AICRP has so far not endeavored in the field of rodent taxonomy. Considering the great variation in pest species complex, the studies on systematic of rodents may be initiated.

To evaluate the ethological manifestation of rodents towards their exudates and urine To establish the economic threshold level of major pest rodents

As in case of insect pests, there is not much information on threshold levels of rodent pests for different crops/seasons/localities etc. There have been a number of constraints in working out ETL of rodent numbers. It is pertinent to note that the ETL should depend on number of burrows in the areas around the crop fields. This may be done by studying the population dynamics, life tables etc. vis-à-vis their behavioural manifestations.

Refinement of rodent management technology

President methodology on population census, damage assessment, baiting technology, placement of baits and efficacy of various control methods including trapping and cultural techniques needs further refinement for better integration in a viable pest management approach and enhanced adoption by farmers.

Human resource development on rodent control

Presently AICRP is undertaking social engineering activity on rodent control and organizing training programmes at various levels for creating a nucleus of trained personnel in the field of rodent control. In addition to these activities, AICRP proposes to broaden its arena for mobilizing the human resources in rodent management with the active assistance of KVKs, other government and non-government organizations in the country.