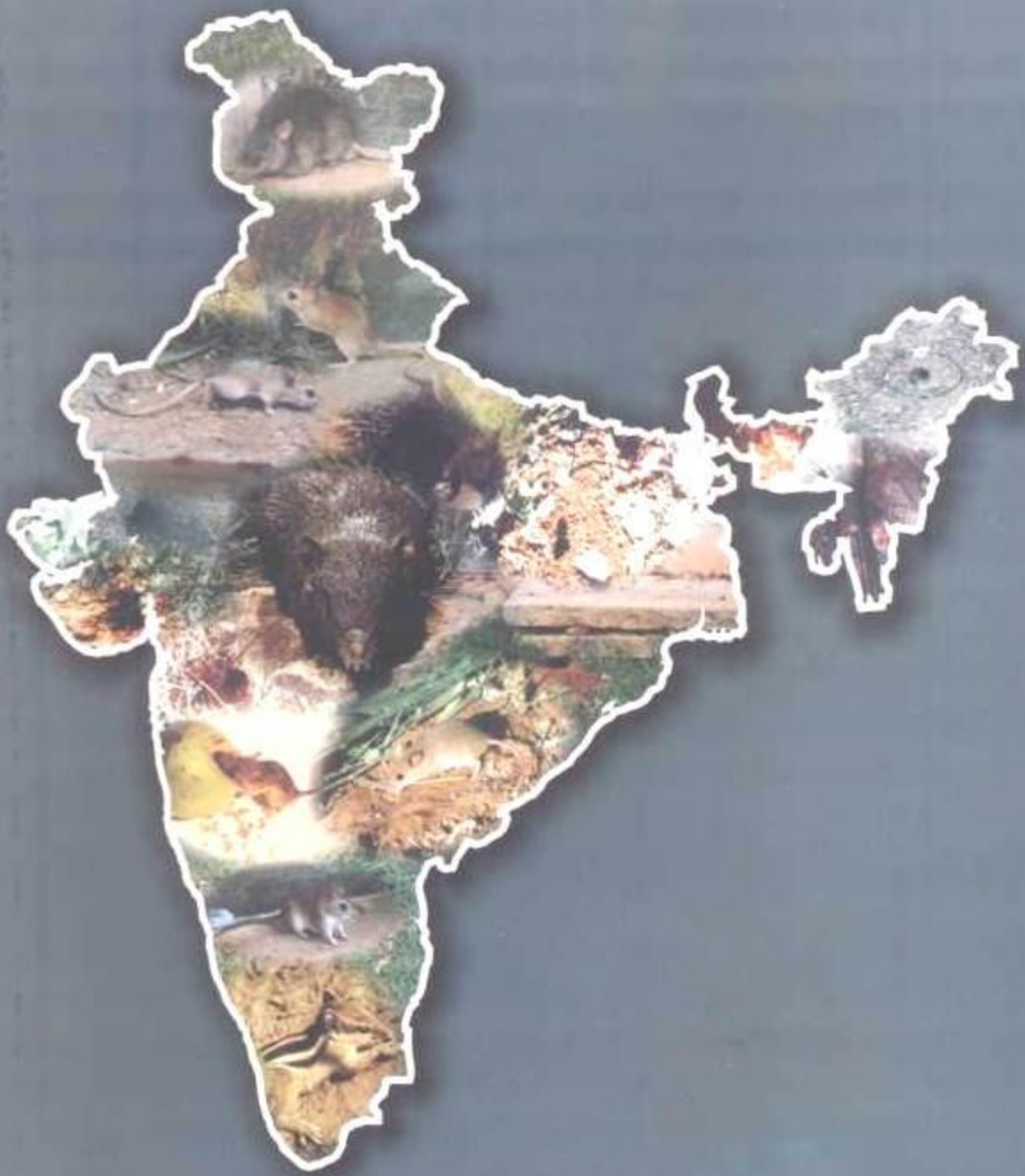
DISTRIBUTION OF RODENTS IN INDIAN AGRICULTURE



NETWORK COORDINATING UNIT

ALL INDIA NETWORK PROJECT ON RODENT CONTROL

CENTRAL ARID ZONE RESEARCH INSTITUTE

JODHPUR - 342 003

Distribution of Rodents in Indian Agriculture

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Technical Bulletin No. : 13

Network Coordinating Unit
All India Network Project on Rodent Control
Central Arid Zone Research Institute, Jodhpur

Published by :
Network Coordinator
(For Indian Council of Agricultural Research)
All India Network Project on Rodent Control
Central Arid Zone Research Institute, Jodhpur

2005

Printed by :
Evergreen Printers
14-C, Heavy Industrial Area, Jodhpur

ICAR

Tel : 91-11-23382257 (O)
91-11-27552557 (R)
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INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Krishi Bhavan, New Delhi-110 001

Foreword

Rodents are the most successful and abundant mammalian group on earth probably next to man and share human and animal habitat and food. These tiny vertebrates maintain a fairly high population levels in agricultural and household situation in the Indian subcontinent where rodent damage to standing crops ranges somewhere between 5-15%. This figure may be much more if their devastating potential in indoor situation, like houses, godowns, ports etc. is included. Their role in spread of several deadly diseases is well known. During the recent plague epidemic in Gujarat, about 4000 persons suffered its infection with about 100 deaths. The Indian Council of Agricultural Research sponsored All India Coordinated Research Project on Rodent Control is engaged in studies on eco-biology and management of pest rodents. The Projects has made steady progress in research and extension on these aspects in different agro-ecological zones of the country.

For evolving an integrated approach to rodent pest management, knowledge about the target species, its distribution and pestilence is the first and foremost requirement. Moreover only about a dozen species, out of 128 species occuring in India are regarded as pests in Indian Agriculture. I am happy to learn that the scientists of the ANIP on Rodent Control have generated voluminous data on this aspect for different agroclimatic regions of the country. The present book is an excellent attempt to compile and collate the information on major rodent pests, their distribution and nature and extent of damage generated for various regions at one place. The distributional aspects of rodent pests covers details in terms of agro-climatic zone, cropping system, habitat range form subterranean to arboreal and extent of crop damage. I am sure, this publication will be of immense help to the rodentologists, policy makers, development officials and extension workers alike.

I congratulate the authors for this timely publication.

New Delhi
Dated the 30 May, 2005

(O.P. Dubey)
Asstt. Director General (PP)

PREFACE

It is a fact beyond dispute that a detailed knowledge of the biology, behavioural ecology and distribution pattern of a pest species is vital for its successful management. It is fairly easy to observe and record the distribution of insect pest/pest complexes in relation to host crop/s because of two major factors mainly their diurnal life style and short life cycles. Amongst conventional mammalian pests, rodents rank first by virtue of the colossal damages they inflict on almost all cultivated crops at some stage or the other, not to mention about their role in disease transmission and material damage. In spite of the historically devastating role they played in the frequent outbreaks of plague in the nineteenth and earlier twentieth century, their well known, acknowledged and accepted depredation on standing crops and stored food, knowledge about the pest status and distribution of rodents in India was awfully poor till early 1960. The lacuna was redeemed to some extent by exhaustive work by Dr. Ishwar Prakash in Rajasthan, Dr. P. J. Deoras in Maharashtra, Dr. S.K. Majumdar and M.K. Krishnakumari at Mysore. Rodent ecology became a serious subject of study from an agricultural point of view only from mid 1960s and early 70s with intense research and extension work taken up by Spillet and Frantz in Calcutta godowns, Chaturvedi and his colleagues in villages around Sidhpur, Gujarat and Dr. A.S. Srivastava and his group in Kanpur, Uttar Pradesh.

The major thrust for agricultural rodentology came with the Department of Science and Technology, Government of India supporting three location specific research on rodents at Bangalore, Punjab and Rajasthan in 1977. The very next year, Indian Council of Agricultural Research launched the All India Coordinated Research Project on Rodent Control at the above three centres and in Kerala (plantation crops) at Kasaragod which was later extended to Andhra Pradesh (1986, Irrigated paddy), Madhya Pradesh (1983, gram and soybean), Uttar Pradesh (1983, Sugarcane-wheat-mustard), Gujarat (1987, Groundnut), NEH region (1982, paddy-maize-pineapple) and Himachal Pradesh (1987, Horticultural crops). The major thrust of the Project was to generate knowledge on rodent species, damage caused and management strategies for major crops/cropping systems in the country.

During the past two decades enormous data has been generated on rodent pests of agriculture leading to standard, practical, workable technology to control rodents across the country. With these inputs rodentology received a boost leading to publication of "Rodent Pest Management (Prakash & Mathur, 1987)" and "Rodents in Indian Agriculture (Prakash & Ghosh, 1992)", the former a "generalist" book and the later a "specialist" one on the subject. Together these volumes provided up-to-date information on major areas of rodent management in the country. The present compendium is more specialized, compiling data on rodent species diversity and abundance in different agro climatic conditions of diverse cropping patterns of the country and estimated losses, a much overlooked area of publication. It is only when facts and figures of losses-both qualitative and quantitative, are projected that public and policy makers will realize the gravity of rodent problem. The next step is which species is the culprit, where and when. Based on this the "HOW" of the management can be planned effectively. The aim of this book is just that.

The genesis of such an idea and the encouragement to bring out such a publication lies in Dr.O.P.Dubey, Assistant Director General (Plant Protection), Indian Council of Agricultural Research, New Delhi, who sat through the biannual workshops of AICRP on Rodent Control all through these years and gave a new perspective to ongoing research. But for his fortitude and futuristic vision this monographic compilation would never have been conceived. We extend our deep sense of gratitude and thanks to Dr. Dubey for providing encouragement and writing the foreword of this monograph.

We are extremly grateful to Indian council of Agricultural Recearch, New Dehli and Director, Central Arid Zone Research Institute, Jodhpur for providing financial assistance and adminstrative approval and other necessary facilities for publication of this Monograph.

The principal investigators of the Project in different centres and other rodentologists across the country have contributed immensely by providing all the needed information and patiently put up with our endless enquiries and persistent demands. They all deserve more than our gratitude. We sincerely thank them, specially Drs.V.R. Parshad (PAU Ludhiana), B.C.Dutta (AAU Jorhat), S.M. Zaheeruddin (ANGRAU, Maruteru), P. G. Butani & H.J. Vyas (GAU Junagadh), K.N. Ponnamma (CPCRI Kasaragod), K.C.Sharma, (Dr. YSPUH&F, Solan), N.S.Azad Thakur and A.N.Shylesha (ICAR Research Complex for NEH Region, Barapani Meghalaya), D.C.Srivastava (IISR, Lucknow), P. Neelanarayanan (AVC College, Mayiladuthurai), R.N.Bannerjee (ZSI, Kolkata), Reena Chakraborty (ZSI, Kolkatta)

Our colleagues Mr. V.Shivayya, T.Raveendra Babu, A.Ravishankar, A.C.Shivaji, Ramaiah, Rajanna and Munivenkataramanappa of UAS, Bangalore and Dr. Vipin Chaudhary of CAZRI, Jodhpur have been of tremendous help during the preparation of this monograph by providing library inputs, proof corrections, computer settings, administrative help etc. Ms. Archana S. Shet patiently and deligently sat day and night to complete this compilation as per schedule. We owe a lot to her impeccable computer assistance, inexhaustible patience and genuine interest in the preparation of this compendium.

Shakunthala Sridhara
R.S. Tripathi

CONTENTS

INTRODUCTION

Modern agriculture requires authentic and detailed information on various agroclimatic parameters like soil types, rainfall, temperature, water resources etc. for optimum cultivation. Planning commission of India (Khanna, 1989) has categorized 15 resource development regions in the country, 14 in the mainland and one in the islands of Bay of Bengal (Andaman & Nicobar islands) and in the Arabian Sea (Lakshadweep islands) (Fig.1).The regions are :

1. Western Himalayan Region
2. Eastern Himalayan Region
3. Lower Gangetic Plain Region
4. Middle Gangetic Plain Region
5. Upper Gangetic Plain Region
6. Trans Gangetic Plain Region
7. Eastern Plateau and Hills Region
8. Central Plateau and Hills Region
9. Western Plateau and Hills Region
10. Southern Plateau and Hills Region
11. East Coast Plains and Hill Region
12. West Coast Plains and Ghats Region
13. Gujarat Plains and Hill Region
14. Western Dry Region
15. Island Region

In its attempt to regionalize Indian agricultural economy the Planning Commission has tried to integrate developmental plans of the agroclimatic regions with similar plans of State and Nation. The ultimate goal is to strategise cultivation practices for the fifteen agroclimatic regions so as to develop policies for faster agricultural development at regional level.

In the agro climatic regional planning further sub-regionalization on the basis of specific agro-ecological parameters was considered. These sub zones were delineated on the basis of soil, topography, climate and water resources The Indian Council of Agricultural Research, New Delhi initiated National Agricultural Research Project (NARP) in different agro climatic zones of India in 1979. The primary objective of this Project was to conduct need based, location specific research in each agroclimatic zone with a zonal research station as the focal point of research. Based on the analysis of agro-ecological conditions and existing cropping patterns it was planned to develop a balanced and coherent research programme to identify and solve the major problems limiting agricultural growth in the zone.

Under the NARP zoning was mainly based on ecological land classification taking into account factors like soils, climate, topography, vegetation, crops etc. Zones were contiguous areas within the state boundary and have homogeneous topography, rainfall, soils, cropping patterns and irrigation facilities. In general each agroclimatic zone comprises of 2-4 districts spreading over 40-50 thousand sq.km. Under NARP 131 agro climatic zones for 17 major states and 9 union territories were identified.

1. Western Himalayan Region
2. Eastern Himalayan Region
3. Lower Gangetic Plain Region
4. Middle Gangetic Plain Region
5. Upper Gangetic Plain Region
6. Trans-Gangetic Plain Region
7. Eastern Plateau & Hills Region
8. Central Plateau & Hills Region
9. Western Plateau & Hills Region
10. Southern Plateau & Hills Region
11. East Coast Plains & Hills Region
12. West Coast Plains & Ghats Region
13. Gujarat Plains & Hills Region
14. Western Dry Region
15. Island Region

Fig. 1 Agro-climatic zones of India (Ghosh, 1991)

The All India Co-ordinated Research Project on Rodent Control was initially implemented in the states of Rajasthan, (Central Arid Zone Research Institute, Jodhpur) Karnataka (University of Agricultural Sciences, Bangalore) and Punjab (Punjab Agricultural University, Ludhiana) during 1978. Later on it was extended to Kerala (Central Plantation Crops Research Institute, Kasaragod), Andhra Pradesh (Agricultural Research Station (ANGRAU), Maruteru), Madhya Pradesh (Jawahar Lal Nehru Krishi Vishwa Vidyalaya, Jabalpur), Gujarat (Gujarat Agricultural University, Junagadh), Himachal Pradesh (Dr. Y.S. Parmar University of Horticulture & Forestry, Solan), Northern Eastern Hill States (Indian Council of Agricultural Research complex for NEH region, Barapani, Shillong) Uttar Pradesh (Indian Institute of Sugarcane Research, Lucknow) and Assam (Assam Agricultural University, Jorhat). However the centres at Kasaragod, Junagadh, Jabalpur and Solan were closed during the IX and X Plans. The Project is now referred as All India Network Project (AINP) on Rodent Control.

One of the major and most important mandates of AICRP on Rodent Control is SURVEY, SURVELLIANCE AND MONITORING OF RODENT PESTS IN DIFFERENT AGROCLIMATIC ZONES of the country.

If we fit the research data of AICRP on Rodent Control into the map of Planning Commission delineating India into 15 agro-climatic regions of the country, data has been generated for species composition of rodents for parts of Western Himalayan Region (Himachal Pradesh), parts of Trans Gangetic Plain (Punjab), Western Dry Region (Rajasthan), Gujarat Plains & Hill Region (Gujarat), Upper

Gangetic Plain (Uttar Pradesh), Eastern Himalayan Region (North Eastern Hill states & Assam), West Coast Plains and Ghats Region (parts of Kerala and Karnataka), and Southern Plateau and Hill Region (most of Karnataka, parts of Andhra Pradesh & Tamil Nadu). The Project, therefore could not generate data on rodent research in Middle Gangetic Plains (Bihar), Western Plateau and Hills Region (Maharashtra), Eastern Plateau and Hills Region (Orissa), East Coast Plains and Hills Region (Coastal Tamil Nadu, Andhra Pradesh, Coastal Orissa) and Lower Gangetic plain region (West Bengal).

RODENT PESTS OF AGRICULTURE

A pest is defined as "an animal that causes harm to humans, their crops, livestock or possessions". Organisms that inflict discomfort, annoyance, trouble and nuisance are also called pests.

Of the 128 species of rodents belonging to 46 genera in India about a dozen qualify as pests, three to four may become occasional pests, some are localized pests and a few of them are pests of National significance. The main damage by rodents is to agricultural produce both in the field and in storage. They also cause damage to machinery, doors, windows, buildings and roads by their gnawing activity. A large number of diseases including bubonic plague, leptospirosis, murine typhus etc. are transmitted actively or passively i.e. as reservoirs or vectors by rodents. The earlier record of their nuisance has been documented in detail by Barnett and Prakash (1975), Prakash and Mathur (1987) and Ghosh and Prakash (1992). Scientists of Indian Council of Agricultural Research working in the Project in different agro-climatic zones of the country since 1978 have generated huge amount of data on the species diversity in different agro-ecosystems and cropping conditions, bio-ecology of pest species, toxicity of rodenticides and evaluation and formulation of rodent management strategies. Based on these works this compendium attempts to give an in depth, update information on the rodent infestation, species abundance and damage caused in different cropping situations in India. The book shall have chapters on major rodent pests of India with a brief description of species and its pest status, followed by consolidated information on crop and area specific rodent distribution and damage across the major agro-ecological conditions of the country based on the data collated by All India Co-ordinated Research Project on Rodent Control. The states include Andhra Pradesh, Assam, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, North-East Hill region, Punjab, Rajasthan and Uttar Pradesh. In addition, information available for West Bengal, Tamil Nadu, Maharashtra and other states from other sources have also been highlighted. The last chapter attempts to work out the crop losses due to rodents to hightlight the role of rodents in yield losses of different crops across the country.

MAJOR RODENT PEST SPECIES OF INDIA

1. The Northern Palm or five stripped squirrel, *Funambulus pennanti* (Wroughton 1905) (Family : Sciuridae)

F. pennanti is a medium sized squirrel weighing 90g with a bushy tail. The dorsal side is greyish brown with five distinctly white stripes separated by four off white bands. Tail is white with a blackish midportion and tail tip is whitish. Soft fur covers the small ears (Plate 1).

Distribution : India, Pakistan, Nepal and parts of Iran. Within India its distribution ranges from south of Sikkim to the northern district of Dharwad in Karnataka, from Baluchistan to West Bengal. It is also reported from Andaman Island (Fig. 1).

Habitat : Although the northern palm squirrel generally lives close to human habitation, orchards, gardens, parks and in areas with fairly good number of trees, wild populations of the species are also found in forests. In the wild, rocky habitat with dense cover of trees are preferred. The squirrel nests in holes in tree trunks as well as crevices in the walls of buildings, window sills, compounds etc. Females during breeding construct nests using twigs, rags, hair etc.

Habits : It is highly active, playful, arboreal and running around up and down the trees, chirpy and diurnal. Peaks of activity occur in the morning and early evenings.

Breeding : The female squirrel reaches sexual maturity by about 6-8 months of age. Although reported to breed throughout the year (Bannerjee, 1955 & 1957), breeding is generally seasonal from March to September with peaks during March-April and July-September in Rajasthan (Purohit *et al.*, 1966) and from February to September in Delhi (Seth and Prasad, 1969). Gestation lasts 40-42 days and litter size varies from 1-5. The young are weaned after 30 days and reach adult size in four months.

Food : They generally consume fruits, nuts, seeds, flowers etc. but being omnivorous eat insect larvae, beetles, moths etc.

Pest status : *F.pennanti* causes severe damage to fruits like pomegranate, sapota (chiku), grapes, guava and *Zizyphus* (Prakash and Ghosh, 1992). Damage to pineapple in Bangladesh (Posamentier, 1981), pineapple and mango in Nepal (Bruggers and Brooks, 1984) has been reported.

2. The Southern palm squirrel, *Fanumbulus palmarum* (Linnaeus) (Family : Sciuridae)

F. palmarum is a medium sized rodent. Its biology, habit and economic importance are similar to *F. pennanti* as it is its counterpart in southern India. The

main difference is morphological, namely there are three white bands on the dorsal side separated by two off-white bands (Plate 1). Information available about the species is negligible although it is surmised that the biology and behaviour is similar to *F. pennanti* (Fig. 1).

3. The Western Ghat squirrel, *Funumbulus tristriatus* (Waterhouse) (Family: Sciuridae)

F. tristriatus is the largest species of the genus *Funumbulus* weighing around 125g. The dorsal side has three narrow, white or pale buff stripes separated by black or brown bands. The central stripe is thinner and shorter than the lateral ones. Belly is whitish with hair bases distinctly grey.

There are three sub species of *F. tristriatus* viz., *F.t. tristriatus, F.t.wroughtoni* and *F.t.numaris* (Moore and Tate, 1965)

Distribution: *F.tristriatus* inhabits a limited area of Western and South Western India extending from Mumbai down to Travancore in the south, mostly in the coastal areas and the evergreen forests of Western Ghats. *F.t.tristriatus* is the most abundant, living in the central and northern strip of Western Ghats including coastal areas. *F.t.wroughtoni* is the least abundant and lives in non-coastal interiors of Western Karnataka and interior of Kerala while *F.t.numaris* is endemic to coastal western Kerala (Fig. 2).

Habitat : It is quite diverse with almost all types of Western Ghat biome being inhabited by *F.tristriatus*, which include villages, towns, crop fields, orchards, plantations and forests. It lives in nests built using fibrous plants on top of trees in a canopy as well as on the rafts of tiled or thatched building.

Habits : The squirrel is arboreal and diurnal with peak activities in the morning and evenings. Feeding occurs at the same peaks.

Food : The squirrel is an omnivore, eating paddy, male flowers of coconut, termites and caterpillars. In addition, large amounts of fruits like cashew, apple, mango, cocoa, kokra, laurel, insects like black ants and beetles are also eaten. It inflicts heavy losses to cocoa in Kerala and Karnataka (Abraham *et al.* 1979; Bhat *et al.* 1981).

Breeding : The Western Ghats squirrel breeds throughout the year with peak occurring from December to May (summer) and with minimum number of breeding females during June-August, the months of heavy rainfall in west coast of India.

Pest status : The squirrel damages the pod in the centre, while the rats damage near the peduncle. The Western Ghat squirrel along with *Rattus rattus* cause 51-60% loss to cocoa in Kerala. In Tamil Nadu and Karnataka the loss reported was 48% and 50%, respectively (Bhat *et al.*, 1981).

4. The Indian crested porcupine, *Hystrix indica* (Kerr, 1792) (Family: Hystricidae)

There are two species of *Hystrix*, viz., *H. indica* Kerr and *H. hodgsoni* Gray.

The crested porcupine is the largest rodent species in India measuring 680-750mm in length and weighing 11-18 kg. The neck and upper back are covered with distinct long, stiff, bristle-like hairs called quills (15-30cm). When the animal is excited the hair stand erect to form a prominent crest. The body is clothed with alternating dark brown and white quills and the tail is covered by short and broad quills. Short, coarse, black hairs thinly cover the ventral surface. The "rattling quills" on the tail are white in colour, large and open (Plate 1).

Distribution : *H. indica* is widely distributed in India, Bangladesh, Nepal, Sri Lanka, Pakistan, extending to Israel, Arabia, Southern and Eastern Russia (Fig. 3). *H. hodgsoni* Gray is found only in the central and eastern Himalayas, Assam and lower Bengal upto an altitude of 1500m. This species is characterised by a very small, rudimentary crest which may be absent often (Fig. 3).

Habitat : Indian Crested Porcupine is highly adaptable, occurring throughout the Indian subcontinent from valleys upto 2750 meters altitude. It is found in moist deciduous forests, forest plantations, rocky hillsides, sandy deserts, ravines and valleys stretching from Himalayas to Kanyakumari. It is less common in alluvial plains and rare in intensively cultivated areas.

Habits : Porcupines live in caves, amongst rocks, in tunnel dug by them or in burrows dug by other animals. During crop maturity they lie in thick shrub near cultivated fields or taking shelter amidst the nearby tall grass, if available.

The mouth of the burrow of porcupine is surrounded by large quantity of earth and is strewn with bones and horns, which are gnawed by porcupines to obtain calcium for the growth of their quills. Apart from the main opening, there are two-three bolt holes for emergency escape around the mouth of the burrow. Burrows can extend upto 18m in length, and 1.5m deep, leading to a large square chamber (Plate 1).

Porcupines are nocturnal with an acute sense of smell. When irritated or alarmed, the spines on the body become erect, the animal grunts and puffs simultaneously rattling its hollow tail quills. By launching itself backwards with high speed, it lodges its hindquarters against the enemy's body and drives its erect quills deep which is fatal to the attacked animal.

Food : Porcupines are known to be chiefly herbivorous feeding on succulent tubers, bulbs, ripe fruits and bark of trees. Grain, vegetables of all kinds and roots are also consumed.

Breeding : Porcupines breed throughout the year. Gestation lasts 109-112 days. Litter size ranges 1-4 (Prakash, 1971).

Pest status : They can be very destructive to gardens and cultivated crops by tunnelling beneath the walls and hedges in order to access the food. Although estimated losses to agriculture are not available, they cause considerable yield loss to maize, sugarcane, potato, sweet potato, ripe melons, onion, carrot etc apart from damaging forest plantations by their girdling behaviour.

5. The Indian gerbil, *Tatera indica* (Hardwicke, 1807) (Family: Muridae, Subfamily: Gerbilliane)

Belonging to the same family as rats and mice i.e. Muridae, but in a different sub family, gerbilliane, the Indian gerbil is distinctly different from rats by its tail, hind feet, ears and eyes. The tail, unlike the naked type in rats and mice is covered with hair, which terminates at the tip as a tuft. The hind feet are longer than fore feet. Eyes are large and ears round. Generally light brown in colour, varying from sandy brown to grey on the dorsal side and pure to off white ventrally. Feet are white, in colour. A light brown band runs along each side of the tail. It is also known as antelope rat due to its large beautiful eyes (Plate 1). The body weight of Indian gerbils ranges from 100-150g for males and 70-100g for females. Variation in colour and other minor characters has led to identification of four distinct races namely *Tatera indica indica* Hardwicke, *T. indica cuvieri* Waterhouse, *T.indica hardwickei* Gray and *T. indica ceylonica* Waterhouse. Several authors have recorded decrease of body size and increase in the length of tail and ear with increasing aridity of the land (Jain *et al*, 1975; Rana *et al.*, 1975; Prakash and Kumari, 1979). The species is also regarded as reservior of plague bacillus.

Distribution : The range of *T. indica* extends westwards to Iran, Syria, Turkey, Iraq, Arabia, Afghanistan, Pakistan and southwards to Sri Lanka. However, the two races, *T. indica cuvieri* and *T. indica hardwickei* are restricted to Indian sub-continent (Ellerman, 1961). The species is ubiquitous occurring throughout India from Himalaya to Kanyakumari (Fig. 4).

Habitat : *T.indica* inhabits open plains, loose sandy soils of the desert, and is usually found at the edges of cultivation. Burrows are dug near hedges, thickets or under bushes, sometimes inside the field also when conditions are dry. In irrigated fields or fields under the threat of floods, high level ground is preferred for burrow construction. Burrows are easy to notice with beaten paths or runways leading from one opening to another. Males and females are reported to live in separate, distinct burrows. The burrow of a male is characterised by a single entrance while that of a female has several openings. The opening leads to a chamber at about 15cm depth. There is a bolt hole for emergency escape. The exit hole may be covered with a thin crust of soil (Plate 1).

Habits : Gerbils are nocturnal. At the slightest alarm, they move in leaps and bounds, sometimes clearing 1.2 to 1.5 m distance in a single leap.

Food : Main food is grains, roots, leaves and grasses. When density is high they are destructive to almost all kinds of cultivated crops at every stage and are also known to hoard food in their burrows (Prater, 1980). During lean season they eat roots, leaves and fruits of wild plants. They quickly adapt to consuming insects and their eggs, eggs and young of ground nesting birds and probably smaller rodents.

Breeding and reproduction : *T.indica* breeds throughout the year in arid Rajasthan with maximum littering in the month of August and a minor peak in February (Jain, 1970; Tripathi, 2005). In Karnataka peak reproductive activity was seen during October-December with a mean litter size of 6. The breeding rate (productivity) was calculated to be 53 young/female/breeding season (Govind Raj and Srihari, 1987).

Pest status : Because of its preference to live and feed on cultivated crops, *T.indica* is a serious pest of all crops in the arid zones, on millet, jowar, vegetables, maize, groundnut and pulses in other states. But to pinpoint exactly the yield losses to gerbils is difficult as they live in association with other rodent pests namely, *Meriones hurrianae, Gerbillus gleadowii, Gerbillus nanus, Nesokia indica, Bandicota bengalensis, Golunda ellioti, Mus booduga and Millardia meltada* in different parts of Rajasthan. In Haryana, Punjab, Gujarat, Uttar Pradesh and Karnataka they are reported to be associated with *B.bengalensis, M.meltada, Mus playthrix* and *M.booduga* and contribute significantly to total losses due to rodents.

6. The desert gerbil, *Meriones hurrianae* (Jerdon) (Family: Muridae, Sub family: Gerbillinae)

The adult body weight of *M. hurrianae* is 40-160g., colour is sandy grey to brownish grey dorsally and white to off-white ventrally. Tail is pale with black or dark brown tussle of hair at the tip (Plate 1).

Distribution : Geographically the genus *Meriones* occurs from Morocco in North Western Africa to the Indian desert in the east, to Russia through the deserts of China, Mongolia and Manchuria in North China. In India distribution of *M. hurrianae* is restricted to Northwest desert of Rajasthan, adjoing regions of Punjab, Haryana and North West Gujarat (Fig. 4).

Habitat : Although it lives in almost all the habitats of Thar Desert, it prefers sandy habitat most. Next in preference is the ruderal habitat followed by gravel plains. Burrows are elaborate, criss-crossing like a honeycomb. They can go upto 1m deep and have an emergency exit hole. Desert life has rendered them less parasitic on man and thus burrows can be found not only near cultivation but far away in waste lands, thorny forests, and open desert. Sand dunes, banks, wind blown moulds of sand consolidated beneath desert shrubs and plants are also preferred

Funambulus pennanti

Fuambulus palmarum

Hystrix indica

H. indica burrow

Tatera indica and its burrow

Ieriones hurrianae

sites for burrows. Burrows have cooler temperature during summer and warmer in winter. A Single burrow system way have several openings.

Habits : Desert gerbils are diurnal. They are far more gregarious than Indian gerbils but live in smaller colonies. They are most active during early morning and evening hours in summers and from sunrise to sunset in winters. When alarmed the desert gerbil makes a drumming sound by stamping its hind legs on the ground and raising its tail.

Food : Although herbivorous, the diet selection is influenced by availability of food with a definite seasonal pattern. Seeds form the major diet during winter, rhizomes and stems in summer months, to some extent insects also, and in rainy season leaves and flowers form the bulk of the food consumed.

Breeding and reproduction : Females breed throughout the year with two peaks in February and July (Prakash and Ghosh, 1992, Tripathi 2005) but a third peak was observed during September-November (Kaul and Ramaswami, 1969).

Pest status : *M.hurrianae* is a common pest of bajra, wheat, chillies, vegetable crops, grass and other vegetation.

7. The hairy footed gerbil, *Gerbillus gleadowii* (Family: Muridae, Sub family: Gerbillinae).

Like *M. hurrianae* this gerbil is also a true xeric fauna and occurs in the sandy plains and inter dunal spaces is western Rajasthan (Fig. 5; Plate 2). It is small sized rodent with sand coloured dorsum and pure white ventrum with a long tail (Tripathi *et al.*, 1992). Peak breeding activity is noticed during May-June and October-January months with a litter size of 2-4 in winters and 5-6 in summer. It is an occassional pest of rain fed crops in Thar desert. At times its depredation to crops has been so devastating that required resowing (Prakash, 1976)

8. The short tailed mole rat, *Nesokia indica* (Gray, 1830) (Family: Muridae Sub family: Murinae)

The species is relatively large weighing more than 200g. The heavily built body is dull to brown on the dorsum and has a lighter ventral side. Tail is short. Fur is short and rough (Plate 2).

Distribution : The species has a wide distribution, spread over India, Pakistan, Iraq, Iran, Egypt, Russia, Afghanistan, Syria, Chinese Turkistan and Northern Arabia; in India it is found only in Punjab, Rajasthan, Haryana, Uttar Pradesh, Himachal Pradesh and Union Territory of Delhi (Fig. 5).

Habitat and Habits : It prefers bunds in cultivated fields along water channels but also occurs in natural vegetation and garden lawns. Prefers soft soil with high

moisture content and good vegetation cover. Nocturnal and fossorial. Burrows are dug preferably at higher levels. In non-irrigated lands burrows are seen only during moist season. Excavates extensive burrows with a heap of soil at the burrow entrance. Ramesh (1992) categorises five types of burrows depending on complexity. Burrows with short tunnels and single opening are found inside the crop fields and are used to take temporary shelter during times of danger while they are out for feeding in the field.

The mole rats are inactive during the severe winter months in northern India, staying inside burrows whose exit holes upto 15-60 cms of tunnel length being filled with soil. When winter comes to a close during February, they emerge from the burrows more actively.The rat is nocturnal with a bimodal circadian rhythm of being active between 18.00h and 20.30h and again at dawn between 6.00h and 7.30h.

Breeding : Although it breeds throughout the year under laboratory conditions, in nature breeding occurs only during winters.

Food : Omnivorous, being commensal the diet is adapted to availability viz., grains, seeds, fruits, tubers, stored products, bakery items, eggs, animal feed and even plantation crops like coconut and cocoa.

Pest status : Feeds on leaves and roots of lawn grass and crops. It is reported to feed on barley, wheat, potato, groundnut, sugarcane, mustard, brinjal, tomato and water melon (Ramesh, 1992) and forestry plantations in arid zone (Tripathi and Jain, 1990).

9. The Bruneusculus rat/Hodgson's rat, *Rattus rattus brunneusculus* (Hodgson, 1845) (Family: Muridae, Subfamily: Murinae)

R.r. brunneusculus is mostly found in hill states of Northeast India. The rat is characterised by white belly and sometimes it may be yellowish or buffy. The dorsal side is brown to greyish brown. Fur is short and soft. Body and tail length are equal i.e. 14-20cm. The elongated head ends in a pointed snout. Although tail appears naked, there are signs of hair all along the tail (Plate 2).

Distribution : Found in Nepal, Sikkim, Mizoram, Assam, Meghalaya, Nagaland and Manipur.

Habitat : It is reported to occur preferably in paddy fields and also known to occur in hilly slopes, jhums (shifting cultivation), forest and in tribal settlements.

Habits : It is nocturnal living in underground burrows, which may range from simple burrows to complex burrow system. They resemble the burrow systems of B*andicota bengalensis* but with smaller dimensions. The oval burrow opening leads to a horizontal undulating passage (4-8 cm in diameter) with 2-4 openings.

At intervals the passage expands into nesting and hoarding chambers. The latter are stocked with paddy, vegetable depending on the availability.

Breeding : Peak breeding was observed from June to August.

Food : Mostly paddy and maize; in its absence vegetables and bamboo seeds.

Pest status : Causes considerable damage to paddy and maize. It is reported to cause famine like conditions as a result of massive increase in population which coincides with cycle of bamboo flowering in North-east India.

10. The soft furred field rat or metad, *Millardia meltada* (Ryley) (Family: Muridae, Subfamily: Murinae)

The metad, *Rattus (Millardia) meltada* weighs 40-60g. Fur is very soft. Body colour light to dark grey dorsally with foot and belly being off white. Tail similar to body colour with dark grey above and pale below (Plate 2).

Distribution : It is widely distrubuted throughout India except the north-east mountainous areas (Fig. 6).

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

Habits : Nocturnal. It occupies the cracks and crevices in the dried up crop fields after harvest as well as the deserted burrows of other rodents. Also it digs simple and shallow burrows (Plate 2).

Breeding : In Karnataka the breeding season for *M.meltada* extended from July to early March with peak reproduction during September- November. The annual productivity was 53-young/female/breeding season. (Govind Raj and Srihari, 1989). In Rajasthan, metads bread throughout the year with peak reproduction occurring in March-October (Rana and Prakash, 1984).

Pest status : *M. meltada* is a serious pest of kharif crops like ragi (*Eleusine coracana*), jowar, maize, groundnut, cotton, til (*Sesamum indicum*) and moong (*Vigna radiata*). During rabi they inflict damage to wheat, barley and brown sarson (*Brassica campestris*). They are also reported to cause damage to natural grasslands and fodder crops in Rajasthan.

11. The Himalayan rat, *Rattus nitidus* (Hodgson, 1845) (Family: Muridae, Subfamily: Murinae)

R. nitidus weighs 100-175g with its body covered by soft fur. It is dark brown on the rump with yellowish to whitish feet which may be dark occasionally. Belly is grey or white or brownish. Tail is dark and naked (Plate 3).

Habitat and Habit : It is nocturnal and commensal.

Distribution : North east hill regions of India and Kumaon in Uttar Pradesh (Fig. 7).

Pest status : Damages paddy, pineapple and maize.

12. Wroughton's rat, *Rattus rattus wroughtoni* (Hinton, 1919) (Family: Muridae, Subfamily: Murinae)

This is actually a distinct sub species of *Rattus rattus* with characteristic white belly. It weighs around 95g (Palte 3).

Distribution : *R.r.wroughtoni* has been reported from southern India (Jain, 1979) and Maharashtra (Deoras *et al.*, 1975). It is found abundantly in the semi evergreen forests, scrub jungles, teak plantations of Karnataka (Sreenivasan, 1975), throughout the state of Kerala in houses, coconut palms and tree cavities (George *et al.*, 1980) and is a serious pest of coconut in Kerala, Karnataka and Andhra Pradesh (Bhat, 1990; Reddy, 1998) and of areca nut and cocoa plantations in Kerala and Karnataka (Bhat *et al.*, 1990)

Habitat and Habits : *R.r.wroughtoni* is an arboreal rodent spending more than 80% of time on tree tops (Bhat and Sujatha, 1986). It lives in nests constructed in tree holes in forests and either in the interspace of nuts or inside stipules in the spindle portion of coconut.

Food : Although food habits in the wild are not known, it is reported to be omnivorous (Advani and Bhat, 1985). Wild fruits and seeds of several plants apart from coconut, cocoa, cottonseeds and oil palm seedlings are reported to be eaten (Rajagopalan, 1966; Advani, 1984; George *et al.*, 1980; Bhat *et al.*, 1990).

13. The Norway rat, *Rattus norvegicus* (Family: Muridae Subfamily: Murinae)

R. norvegicus is primarily a temperate zone rodent both commensal and field pest. Its distribution in India is limited to harbour cities of Mumbai and Kolkota. In recent years its presence in uraban locale of NEH region has also been reported. It is nocturnal and commensal in India and weighs 250-350g. Body brownish dorsally and ventrum whitish or off white (Plate 3). Although inhabits sewers elsewhere, in

Kolkota and Mumbai yet it digs burrows in godowns and is a warehouse pest (Jain *et al.*, 1993).

14. The Indian bush rat, *Golunda ellioti* (Family: Muridae, Subfamily: Murinae)

Not much information is available about this species whose distribution is limited to North-west arid zones of Rajasthan, Punjab and Gujarat (Plate 3; Fig. 8). Nocturnal and fossorial, digging burrows in scrub, thorny and bushy plantations, and around crop fields. Reported to be a minor pest of agriculture in Punjab and Rajasthan (Saini and Parshad, 1993; Prakash and Mathur, 1987).

15. The house mouse, *Mus musculus* (Linnaeus, 1758) (Family: Muridae, Subfamily: Murinae)

The house mouse, *M. musculus* is a tiny animal weighing 15-20g. Tail is naked and longer than body length. Dorsally, the colour varies from brown to light brown with belly being whitish or light grey (Palte 3).

Distribution : Throughout the world.

Habitat and Habits : Commensal, nesting in rafts, crevices in walls, amidst staked undisturbed bags of food grains in godowns, table draws; often lives in fields digging burrows. Nocturnal.

Pest status : Being commensal it is a nuisance to many items in addition to spilling and spoiling a lot more than eating. In fields it is known to damage sugarcane, groundnut etc. By cutting wires it causes power failures and computer shut downs which are financially disastrous by affecting production.

16. The Brown spiny mouse, *Mus platythrix* (Bennet, 1832) (Family: Muridae, Subfamily: Murinae)

M. platythrix is sympatric with elliot's mouse, *Mus saxicola*. Body weight ranges 20-30 g with the fur composed of entirely flattened spines. The dorsal fur is coarser than the belly. The colour is sandy to brown dorsally and white ventrally. The colour pattern is sharp and distinct.

Distribution : occurs from Deccan to Punjab northwards and to Bihar eastwards but absent in North-East and Jammu & Kashmir (Fig. 8).

Habitat & Habits : Found in crop fields, prefers rocky and gravely habitat. The mouse is burrow dwelling and nocturnal. The burrow opening is characterised by arrangement of pebbles, small stones and broken earthware in concentric circles. A significant quantity is collected inside the burrow also (Palte 3). The burrow has

1-3 surface openings with a mean length of 295mm and a mean depth of 12cm with one bed chamber (Malhi *et al.*, 1987). But Chandrahas (1974) reported that the species occupies burrows deserted by other rodents.

Breeding : *M.platythrix* breeds all round the year with a peak during October to January in Andhra Pradesh and Karnataka. (Anon, 1990; Chandrahas, 1974), from June to early March in Karnataka (Govind Raj, 1994). The annual productivity is reported to be 18 in Andhra Pradesh (Rao, 1979; 1981) and 54 in Karnataka (Govind Raj, 1994).

Pest status : Pest of paddy, ragi, wheat, oil seeds and pulse crops.

17. The Indian field mouse, *Mus booduga* (Gray, 1837) (Family: Muridae, Subfamily: Murinae)

M. booduga is a tiny mouse weighing 10-12g. Dorsal fur varying in colour from pale sandy in the desert regions to dark brown to greyish in most regions. Ventrum is white (Plate 4).

Distribution : Throughout India (Fig.9).

Habitat and Habits : *M. booduga* is found in crop fields especially irrigated ones. It is fossorial and nocturnal. Burrows have 2-4 surface openings with a depth of 50-60 cm and length ranging 45-65 cm. The burrows have 1-2 nesting chambers and have smaller openings compared to other species. The one-cm opening is characterised by scooped soil at the entrance with small pebbles (Plate 3). Hoarding upto 7g per burrow is reported.

Breeding : Breeds throughout the year in Punjab, except during very cold months. In South India breeding occurred throughout the year with low reproductive activity during March to July. Annual productivity was 21 young/female/year (Chandrahas, 1974; Rao, 1977). However later studies revealed breeding period from July to March with a peak in September-October and annual reproductivity as 52/female/year in Karnataka (Sridhara, 1999)

Pest status : Pest in rice, wheat, groundnut, raddish etc.

18. The House rat, *Rattus rattus* (Linnaeus, 1758) (Family: Muridae, Subfamily: Murinae)

It is a medium sized rat weighing 150-200g. *R.rattus* is also called as roof rat, black rat and ship rat. It is the most abundant and widely distributed rodent species in India as well as the world. Biswas and Tiwari (1969) recognized at least 14 subspecies within our country. It is characterised by long tail, slender body

and pointed snout as well as the belly. The dorsal fur is mostly blackish in commensal forms which range to yellow to brown black with pale white belly in wild forms (Plate 4).

Distribution : All over the world.

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

Habits : It is nocturnal and colonial.

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

19. The lesser bandicoot rat, *Bandicota bengalensis* (Gray, 1835) (Family: Muridae, Subfamily: Murinae)

There are three recognised sub species of *B. bengalensis* in India namely, *B.bengalensis bengalensis* (Gray), *B.b.varius* (Thomas) and *B.b.wardi* (Wroughton). It is also called the Indian mole rat.

The lesser bandicoot is robust with a round head and a broad muzzle weighing 200-350g. The body is covered with coarse fur which forms black-tipped piles on the dorsal side. The colour on the dorsal side is dark brown but may be blackish, pale brown or reddish. Feet are dark but digits are paler. Tail is completely dark and paler below occasionally. Belly grey or light grey and rarely whitish (Plate 4).

Distribution : Except the extremes of western Thar desert, *B.bengalensis* is widely distributed throughout India, Pakistan, Nepal, Bhutan, Bangladesh, Srilanka and South East Asia (Fig. 5). In recent years it is being reported from urban areas of Jodhpur and Bikaner city.

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

It is completely a fossorial rodent favouring embankments around paddy fields. The burrows are elaborate with several openings. The entrance is characteristically covered with a heap of dug out soil, which are usually small lumps of soil (Plate 4). Burrow opening lead to branching and winding tunnels,

which are interconnected. Several tunnels expand to serve as brood/nesting chambers. Some others are utilised as storage chambers. The number of burrow openings vary from 1 to 16. Depth ranges from 30cm to 100cm and length from 43cm to 450cm. Burrows are dug in crop fields, parks and near garbage dumping yards etc. In godowns burrows are dug even in cemented floor and walls. Considerable amount of grain is hoarded inside the burrows.

The rat is nocturnal. Although reported to be colonial, during breeding season males and females with her young seem to live in separate burrows.

Breeding : The mole rat breeds throughout the year. Definite peaks occur during different seasons across the country. In Karnataka breeding lasts from early July to end of April with peak reproductivity seen during September to October. The annual calculated reproductive rate was 67 young/female/year (Srihari and Govind Raj, 1984).

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

Pest status : The lesser bandicoot is a serious pest of agriculture in India causing extensive damage to paddy, wheat, moong, maize, jowar, ragi, melia, sugarcane, groundnut, pea, many vegetables, and coconut nurseries. Their burrows were also reported from tapioca, calocasia, yam and rubber plantations of Kerala. The burrowing activity of lesser bandicoot rats causes damage to roots causing the slow death of trees/plants in many orchards, plantations and perennial crops like mulberry, apple. Similarly their burrowing activity interferes with irrigation of marshy crops like paddy and leads to indirect losses.

20. The larger bandicoot rat, *Bandicota indica* (Bechstein) (Family: Muridae, Subfamily: Murinae)

B.indica is a very large rat, head and body normally ranging 200mm-366mm. Weight ranges from 500g to 2kg and more. Tail is shorter than head and body is covered with hair throughout its length. The fur is very rough and quite long dorsally. The upper part of the body is dark or blackish brown and ventrum is grey, drab or dark (Plate 4).

Distribution : From the south of Rajasthan down to southern tip of India and eastwards too. Widely distributed in Bangladesh, Myanmar, Malaysia, Thailand, Vietnam, Sumatra, Java, southern China, Hong Kong, Taiwan and Srilanka (Fig. 5).

Gerbillus gleadowi

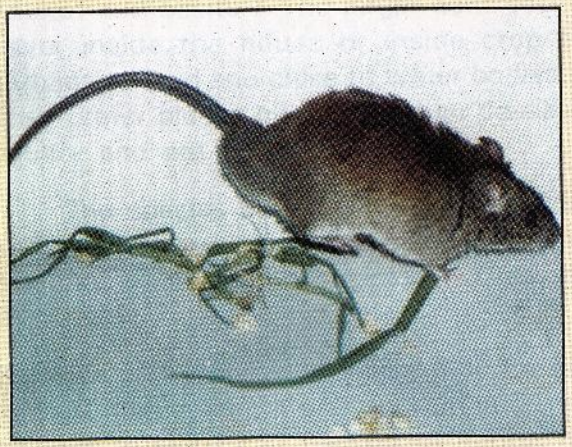
Burrow of *G. gleadowi*

Nesokia indica

Rattus rattus brunneusculus

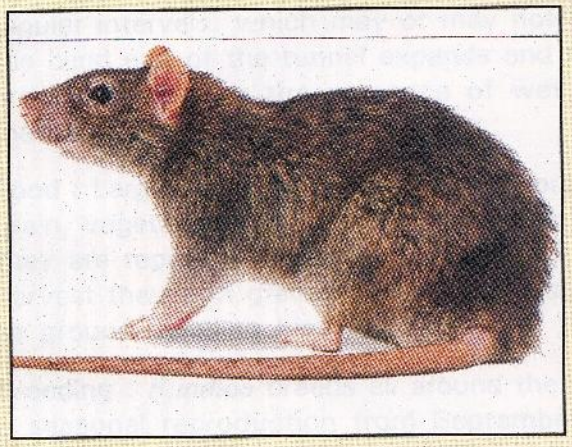
Millardia meltada

Burrow of *M. meltada*



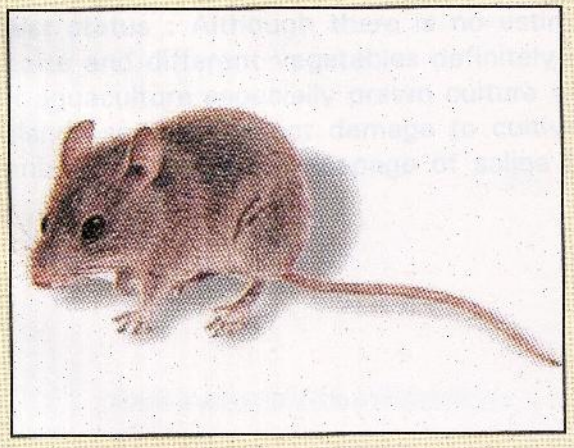
Rattus nitidus

Rattus rattus wroughtoni

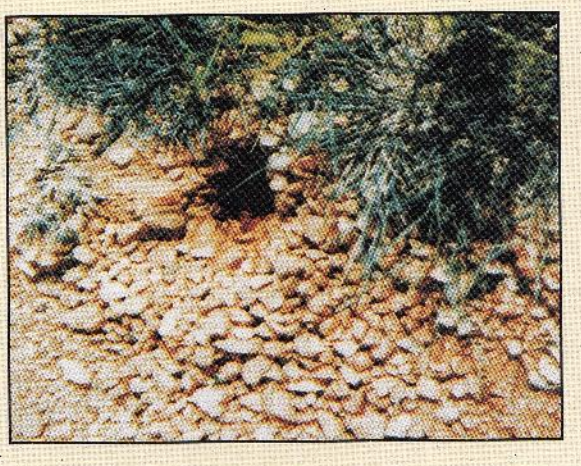


Rattus norvegicus

Golunda ellioti



Mus musculus



Burrow of *Mus platythrix*

Habitat and habits : The larger bandicoot always lives close to human habitat but never inside the house or inside crop fields. It prefers habitat that has lot of garbage to feed and close to water bodies. In south India they are highly commensal. They prefer places close to human dwellings such as compounds, gardens, stables, poultry and out houses.

The species is nocturnal and fossorial. Burrows are found amidst tall grasses and bushes around marshy areas, many a times tunnelled through bricks and masonry of poorly constructed houses, huts in villages, poultry, out houses etc. (Plate 4).

Burrows : The burrow system may be simple consisting of an unbranched tunnel upto 700cm in length and 6-14cm in diameter. These are usually used as temporary shelters to indulge in feeding. A normal burrow system has 1-13 openings leading to tunnels with a diameter of 6-24 cm. Depth may range 40-60cm and extending to a maximum length of 9m. The oblique tunnel from the opening branches at regular intervals, which may or may not be interconnected. One of the tunnels or the blind end of the tunnel expands and forms a brood chamber. Burrow openings are recognised by the presence of wet globules of fresh earth and soft faecal matter (Plate 4).

Food : Larger bandicoot rats are omnivorous and usually feed on household refuse, grain, vegetables and sporadically attack poultry. In Sagar islands of West Bengal they are reported to go underwater and capture fish, molluscs, crabs etc. During harvest they turn grainivorous on harvested paddy and also eat vegetables as well as ground dwelling birds (Chakraborty, 1992).

Breeding : *B.indica* breeds all around the year in West Bengal and Vietnam but has a seasonal reproduction from September to March in India (Chakraborty, 1975; Jain, 1979). The annual productivity at Sagar islands was reported to be 20young/female/year.

Pest status : Although there is no estimate of losses, damage to paddy, wheat, maize and different vegetables definitely occurs. In many areas it is a serious pest of aquaculture especially prawn culture was damaged by its depredation. In deltaic islands serious indirect damage to cultivation is caused by their tunnelling of the embankment causing seepage of saline into paddy fields (Chakraborty, 1992)

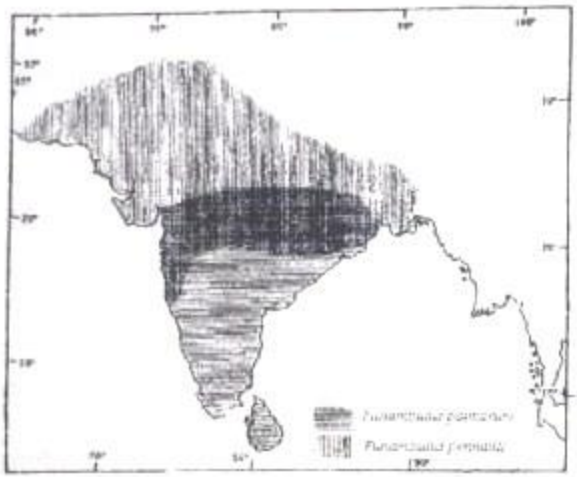


Fig. 1

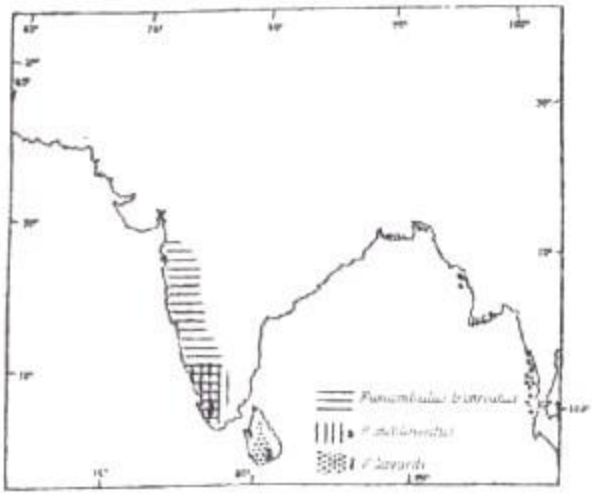


Fig. 2

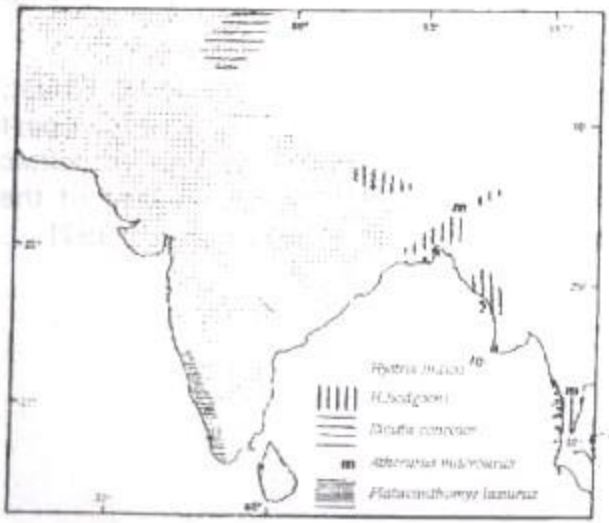


Fig. 3

(From Tiwari & Biswas, 1966)

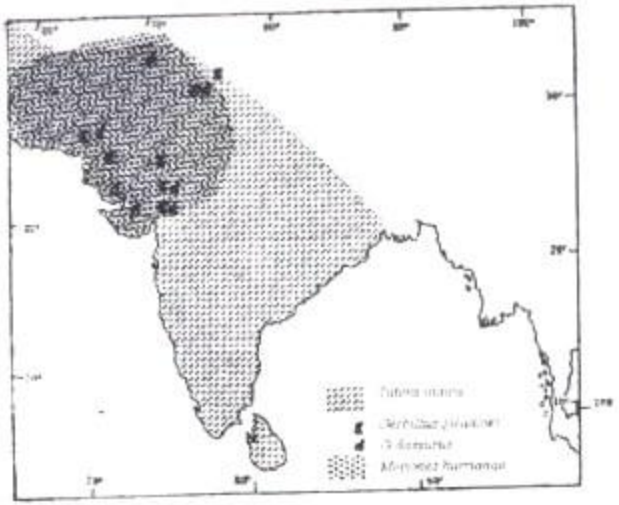
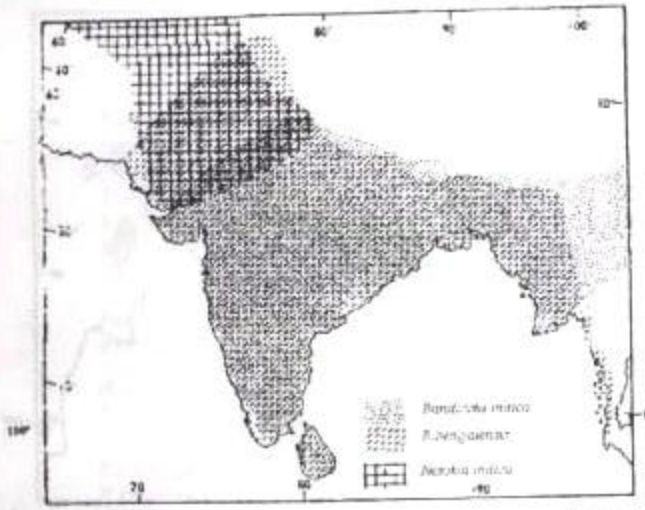


Fig. 4



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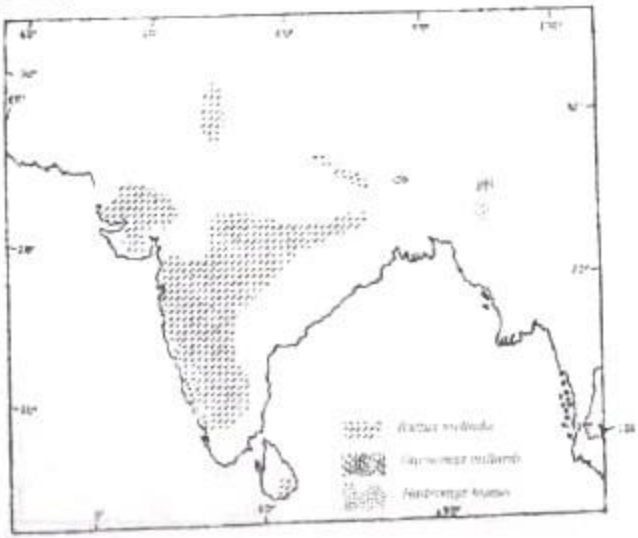


Fig. 6

(From Tiwari & Biswas, 1966)

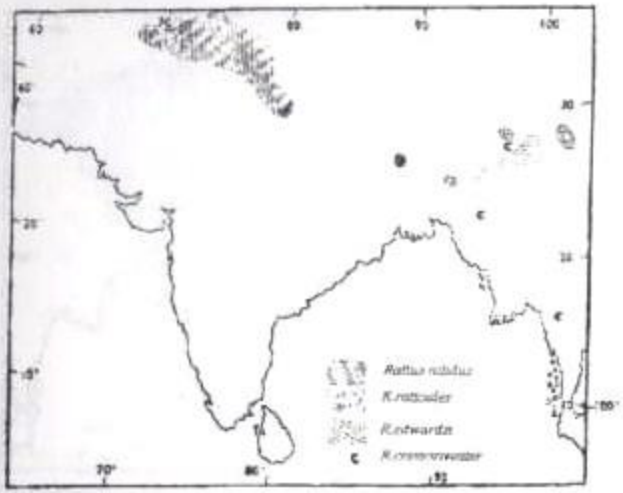


Fig. 7

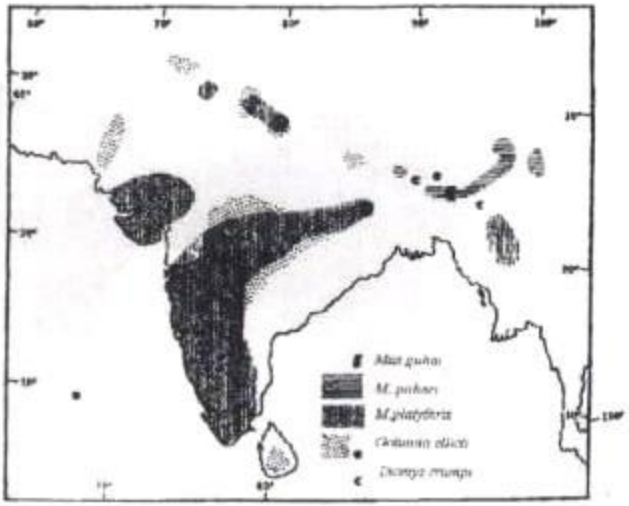


Fig. 8

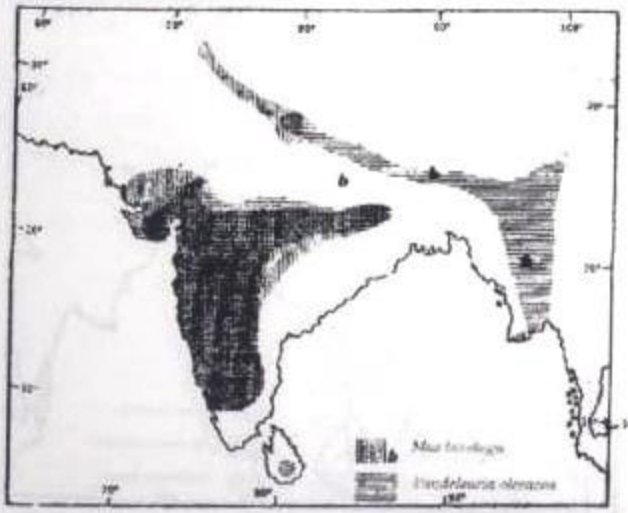


Fig. 9

(From Tiwari & Biswas, 1966)

Table 1: Distribution, habitat and pest status of India rodents

S. No.	Pest species	Distribution	Habitat	Habits	Food	Pest status
1.	***Funanmbulus pennanti*** (Fam. Sciuridae) FIVE STRIPPED OR NORTHERN PALM SQUIRREL	From the south of Sikkim through Indo-Gangetic plains to north of Karnataka, from North-Western desert to West Bengal.	Lives close to human habitation, orchards, gardens, parks and wooded areas. Also found in forests. Hole nesting in tree trunks, crevices in the walls, windowsills and compounds.	Arboreal, highly active, playful, chirpy and diurnal, peak activity in the morning and early evenings.	Generally fruits, nuts, seeds, flowers. Also eats insects, insect larvae, beetles, moth etc	Severe damage to fruits like pomegranate, sapota (*chiku*), grapes, guava and zizyphus.
2.	***Funambulus palmarum*** (Fam. Sciuridae) THREE STRIPPED OR SOUTHERN PALM SQUIRREL	Entire south India.	Similar to ***F.pennanti***	Same as ***F.pennanti***	Similar to ***F.pennanti***	Similar to ***F.pennanti***
3.	***Funambulus tristriatus*** (Fam. Sciuridae) Three subspecies ***F.t.tristriauts F.t.wroughtini F.t.numaris***	Inhabits a limited area of western and south western India from Mumbai down wards south to Trivendrum, the west coast and evergreen forests of western ghats.	Diverse, almost all types of western ghat biome viz. villages, towns, crop fields, orchards, plantations and forests.	Arboreal, Diurnal with peak activities early morning and evenings.	Omnivorous, eating paddy, male flower of coconut, termites and caterpillars. Also cashew fruit, apple, mango, cocoa, kokra, laurel, insects, beetles.	Heavy losses upto 51-60% to cocoa. Damage the pod in the centre.
4.	***Hystrix indica*** (Fam. Hystricidae) INDIAN CRESTED PORCUPINE	Throughout India except higher Himalayas. The subspecies, ***H.hodgsoni*** is found only in Eastern Himalayas, Assam, lower Bengal upto 1500m.	Found in moist deciduous forests, forest plantations, rocky hillsides, sandy deserts, ravines and valleys.	Lives in caves, amongst rocks, burrows nocturnal.	Mainly herbivorous, feeding on tubers, bulbs, ripe fruits, barks of trees, grain, vegetables and roots.	Destructive to garden and crop fields by their burrowing activity. Cause damage to maize, sugarcane, potato, sweet potato, ripe melons, onion, carrot etc. Also damages forest plantations.

S. No.	Pest species	Distribution	Habitat	Habits	Food	Pest status
5.	***Tatera indica*** (Fam. Muridae; Sub family Gerbillinae) THE INDIAN GERBIL	Ubiquitous occurring throughout India from Himalaya to Kanyakumari.	Lives in open plains, loose sandy soils of desert, edges of cultivation, thickets, under bushes.	Nocturnal, move in leaps and bounds.	Main food is grain, roots, leaves and grass. During lean season eat roots, leaves and fruits of wild plants. Also adapted to eat insects, their eggs, eggs and young of ground nesting birds.	Pest of all crops in arid zones, on millet, jowar, vegetable, maize, groundnut and pulses in other states.
6.	***Meriones hurrianae*** (Fam. Muridae; Sub fam. Gerbillianae) THE DESERT GERBIL	Restricted to north west states of Rajasthan, Gujarat and predominantly in the deserts of former.	Prefers sandy, desert habitat, followed by ruderal habitat and gravel plains.	Diurnal, gregarious, most active during early morning.	Mainly herbivorous seasonal preference seen with seeds in winter, rhizome and stems, insects in summer and leaves and flower during rainy season.	Common pest of bajra, wheat, chillies, vegetable crops, and other vegetation.
7.	***R.rattus bruneusculus*** THE HODGSON'S RAT	Found mostly in northeast India.	Occurs preferably in paddy fields, hilly slopes, *jhums* (shifting cultivation), forests and tribal settlements.	Nocturnal, fossorial.	Mostly paddy, also vegetables and bamboo seeds.	Considerable damage to paddy. Reported to cause famine situations due to population outbreaks at the time of bamboo flowering.
8.	***Millardia meltada*** (Fam. Muridae) THE SOFT FURRED FIELD RAT	Found throughout India except north-east mountainous areas.	Predominant pest of rainfed and dry land crops all over the country. Chooses dry patches.	Occupies self dug burrows and cracks, crevices in the dried up crop fields after harvest.	Granivorous	Serious pest of *kharif* crops like ragi, jowar, maize, groundnut, cotton, *til*, moong and during *rabi* damages wheat, barley and brown sarson, grass lands and fodder crops in Rajasthan.

S. No.	Pest species	Distribution	Habitat	Habits	Food	Pest status
9	***Rattus rattus wroughtoni*** (Fam. Muridae) THE WROUGHTON'S RAT	Forests of Karnataka as a commensal and pest of plantation crops in Kerala, in Andhra Pradesh and parts of Maharashtra	Nesting in tree holes in forests and plantation crops, tree canopies in forests and also inhabits houses	Arboreal and Nocturnal	Omnivorous consumes wild fruits, seeds of several plants, seedlings of coconut, cotton seed and oil palm.	Major pest of coconut, cocoa and oil palm
10	***Rattus nitidus*** (Fam. Muridae) THE HIMALAYAN RAT	Mostly found in North-east India and Kumaon in Uttar Pradesh	Occurs preferably in crop fields and bamboo plantations	Nocturnal and commensal	Omnivorous	Damages paddy, pineapple and maize
11	***Rattus norvegicus*** (Fam. Muridae) THE NORWAY RAT	Throughout the world	Commensal, found only in major port cities of Kolkatta, Mumbai etc.	Nocturnal and fossorial.	Omnivorous	Pest in godowns and warehouses
12	***Mus musculus*** (Fam. Muridae) THE HOUSE MOUSE	Throughout India including islands	Commensal in houses, storage structures, eateries, offices, factories and in wild state in crop fields.	Nocturnal Lives in nests in structures. Digs burrows in crop fields.	Omnivorous prefers grains but eats everything that is edible both in raw or prepared forms	Nuisance to household items. Damages sugar cane, groundnut, wheat etc.
13	***Mus platythrix*** (Fam. Muridae) THE BROWN SPINY MOUSE	Entire South India, up to Punjab in the North and upto Bihar eastwards.	Found in crop fields at the edges, prefers sandy, rocky and gravely habitat.	Nocturnal and fossorial.	Omnivorous prefers cereals.	Pest of paddy, ragi, wheat, oil seeds and pulse crops.
14	***Mus booduga*** (Fam. Muridae) THE INDIAN FIELD MOUSE	Throughout India.	Found in crop fields especially irrigated fields	Fossorial and nocturnal	Omnivorous Adaptable to cultivated crops.	Pest in vegetables, paddy and groundnut.
15	***Rattus rattus*** (Fam. Muridae; Sub fam. Murinae) THE HOUSE RAT	All over India and World.	Mostly commensal living in houses, godowns, stores, poultry, edges of crop fields, adjacent to villages, plantation crops especially coconut, open country, forests and hills	Nocturnal and colonial	Omnivorous, eating grains, seeds, fruits, tubers, stored products, bakery items, eggs, animal feed and even coconut, copra	Causes severe damage to coconut, poultry, diary, piggery, godowns, and warehouses. Nuisance to all establishments due to its gnawing activity.

Mus booduga

Rattus rattus

Bandicota bengalensis

Burrow of *B. bengalensis*

Bandicota indica

Burrow of *B. indica*

STATE WISE DISTRIBUTION OF RODENTS

I. ANDHRA PRADESH

Andhra Pradesh is the fifth largest state in the country. Forty two percent of the geographical area of the state is being cultivated providing livelihood to 77% of the population and generating 60% of the income. Based on topography and altitude the state is classified into Coastal Plain, Eastern Ghats and Peninsular Plateau.

CLIMATE AND RAINFALL

The climate is predominantly semi arid to arid except coastal belt which is humid to sub-humid. The four distinct seasons are summer (March-May), South-west monsoon (rainy, June to September), North-east monsoon (October-December) and winter (December to February). The average rainfall is 896mm ranging from 500mm to 1000mm. There are six soil types: red, black, alluvial, coastal sandy, laterite and problem soils i.e. saline, salino-alkali, saline-alkaline.

MAJOR CROPS

Rice is the major crop followed by sorghum, maize, pearl millet, cotton and chillies. Considerable quantities of finger millet, red gram, green gram, black gram, Bengal gram, groundnut, gingilly and castor are also raised. There is significant cultivation of horticultural crops that include mango, citrus, banana, guava, custard apple and vegetable crops like coriander, turmeric, tomato, onion and tapioca.

AGROCLIMATIC ZONES (Table 1; Fig. 1)

With not much variation in soil type and temperature, it is the amount and distribution of rainfall that mainly determines the agro-climatic zones of Andhra Pradesh. Based on these criteria, the state is divided into seven agro-climatic zones namely (1) Krishna-Godavari zone (2) North coastal zone (3) Southern zone (4) North Telangana zone (5) Southern Telangana zone (6) Scarce rainfall zone (Rayalseema) and (7) High altitude and Tribal areas.

The physical characteristics, cropping system and major crops of each of the zones are presented in Table 1 and are as follows:

1. **KRISHNA GODAVARI ZONE** : It comprises the entire districts of W.Godavari, Krishna, Guntur, excluding upland talukas of East Godavari district, Kammam, Nalagonda and Prakasam districts. The soil types are deltaic alluvium, red soils with clay base (Alfisols), heavy, deep to very deep black cotton soil (Vertisols), deep to very deep red loamy soil (Alfisols), coastal sands and saline soils. Rainfall ranges 800-1100 mm and 59% of the crop is irrigated. The predominant cropping

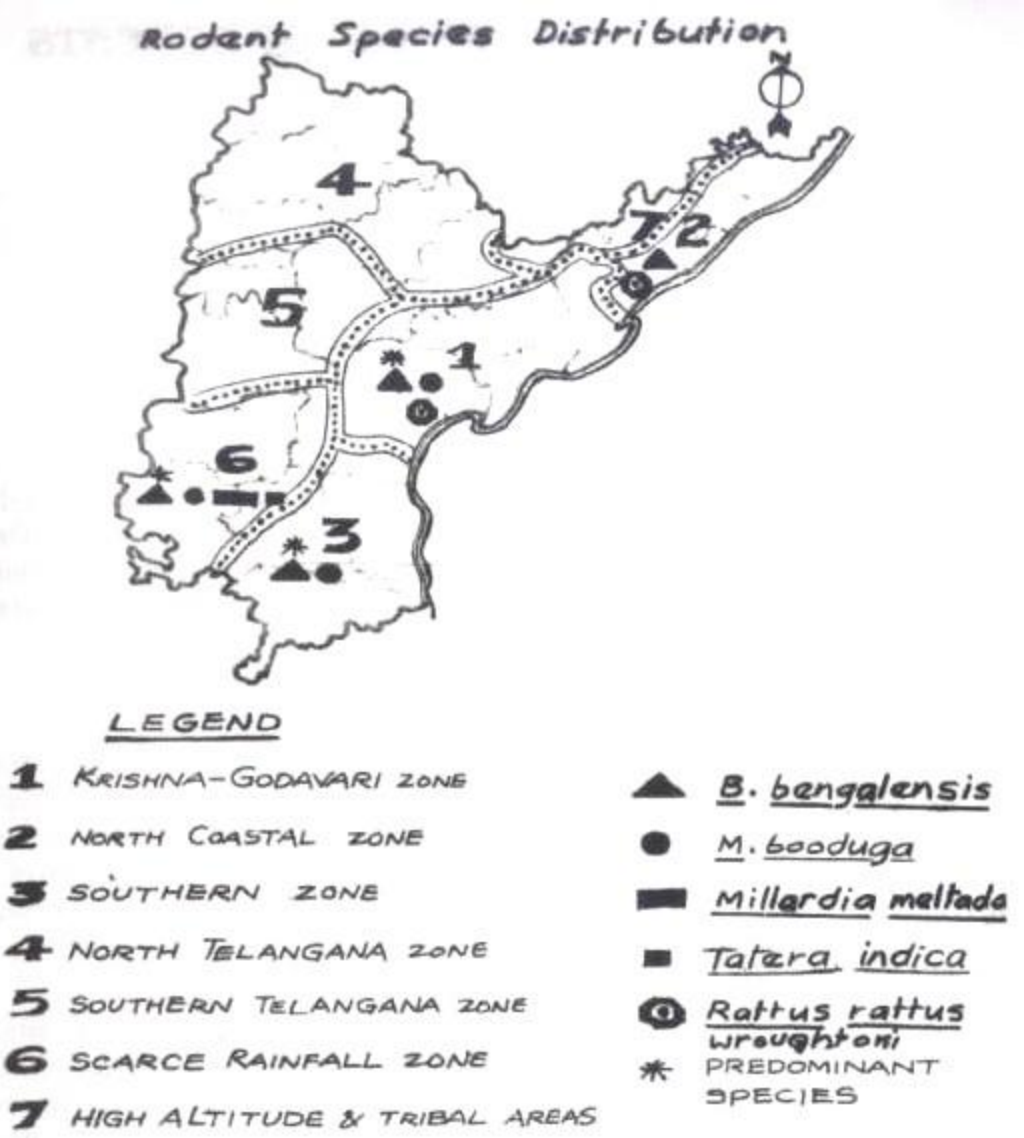


Fig. 1: Agroclimatic zones of Andhra Pradesh and distribution of rodent species

system is rice based. Major crops are rice, cotton, black gram, green gram, groundnut, fodder, tobacco, sugarcane, chillies, coconut and sesame.

2. NORTH COASTAL ZONE : This zone consists most parts of Srikakulam, Vizianagaram, Visakapatnam districts and upland talukas of East Godavari district. The soils are predominantly red with clay base (Alfisols). There are some pockets of acidic laterite soils (Oxisols). Rainfall is in the range of 1000-1100mm and 42% of the cropped area is under irrigation. Major cropping systems are based on rice,

sugarcane, groundnut, pearl millet and finge millet. As such the predominant crops grown are rice, groundnut, pearl mille, mesta, finger millet, sugarcane, sesame, horse gram, green gram and black grm.

3. SOUTHERN ZONE : It includes Nellore ard Chittoore districts and southern parts of Prakasham, Cuddapah and easterr parts of Ananthpur district. The predominant soil group is shallow to moderate deep red loamy soil and red earth with loamy soil. Patches of moderately deep o deep black cotton soils are also present. The range of rainfall is 700-1050mm with 43% of cultivated area being irrigated. The major cropping system is rice an groundnut based. The predominant cultivated crops are rice, groundnut, sorghum,pearl millet, red gram, finger millet and horse gram.

4. NORTH TELANGANA ZONE : Entire districtsf Adilabad, Karimnagar, Nizamabad and Medak except its southern border, Warangal except its western portion, North-eastern tip of Nalgonda and most partsof Khammam fall under this zone. Red soils are predominant in this zone. The typs include red earth with loamy sub soil, red sandy soil, deep to very deep red loaiy soil and deep to very deep black cotton soil. Rainfall range is 900-1150mm andonly 24-60% of agriculture is under irrigation.The predominant cropping system ; sorghum, rice and maize based. Major crops grown are sorghum, rice, maize cotton, groundnut, red gram and Bengal gram.

5. SOUTHERN TELANGANA ZONE : This zoneconsists of Hyderabad, Rangareddy districts, Mahaboobnagar district except its outhern border, Nalagonda district except its eastern part, North-eastern and southern parts of Warangal. The soil is predominantly red soil with loamy subsoil, redsandy, small areas in the west are deep to deep black cotton soil. The rainfall rane is 700-900mm and irrigated area is 23.7% of the total cropped area. The mai cropping system is sorghum, rice and castor based. Major crops cultivated are sorghum, rice, castor, groundnut, pearl millet, green gram, maize and sunflower

6. SCARCE RAINFALL ZONE OF RAYALSEEMA: It includes the districts of Kurnool, Ananthpur except its south eastern part, westrn part of Prakasham, southern part of Mahaboobnagar and north western parts ofCuddapah. The major soil types are red earth with loamy sub-soil, red earth with layey subsoil, red sandy soil, light, moderate deep to deep black cotton and heay, deep to very deep black cotton soil. Rainfall is 500-750mm and only 15.7% f the area is irrigated. Predominant cropping system is groundnut, sorghum, setria, rice, cotton based. The major crops grown are groundnut, sorghum, seteri, rice, cotton, coriander and pearl millet.

7. HIGH ALTITUDE TRIBAL AREAS : This zonconsists of the northern borders of the Srikakulam, Vizianagaram, Vishakapatnm, East Godavari and Khammam

Table 1: Agroclimatic zones and crops of Andhra Pradesh

Zone	Districts & Taluks	Soil type	Rainfall	Cropping system	Rodent pests (species)
KRISHNA GODAVARI ZONE. (59% irrigated crops)	Dts of W.Godavari, Krishna, Guntur, parts of East Godavari, Kammam, Nalagonda & Prakasham dts.	Deltaic alluvium. Alfisols, Black cotton, Red loamy, Alluvial, Coastal sandy.	800-1100mm	Rice based	*Bb, Mb, Rrw*
NORTH COASTAL (42% irrigated)	Most parts of Srikakulam, Vizyanagaram, Visakhapatnam, upland taluks of E.Godavari Dt.	Alfisols, acidic laterite	1000-1100mm	Paddy, Sugarcane, Groundnut, Pearl millet and Finger millet based	*Bb, Rrw*
SOUTHERN ZONE (43% irrigated)	Dts. of Nellore, Chittor Southern parts of Prakasham Cuddapah, Eastern parts of Anantpur Dts.	Loamy Inceptisols-Alfisols, Black cotton	700-1050mm	Rice and Groundnut based	*Mb, Bb*
NORTH TELANGANA (24.6% irrigated)	Adilabad, Karimnagar, Nizamabad Districts. Parts of Medak, Warangal, Nalagonda & Khammam Dts.	Red soil. Red sandy, Red loamy. Deep red loamy, Black cotton, Acidic laterite	900-1150mm	Sorghum, Paddy and Maize based	NA*
SOUTHERN TELANGANA (23.7% irrigated)	Dts. of Hyderabad, Rangareddy. Mahaboobnagar except its southern border, Nalgonda except its eastern border. North-eastern and southern parts of Warangal.	Red soil, Red sandy - deep black, cotton soil.	700-900mm	Sorghum, rice, castor based	NA*
SCARCE RAINFALL ZONE OF RAYALSEEMA (15.7% irrigated)	Ananthpur Dt. except its southeastern part, Kurnool Dt. Western part of Prakasham Dt. Southern part of Mahaboobnagar Dt. North-west part of Cuddapah Dt.	Red earth with loamy subsoil, Red earth with clay subsoils, Red sandy, Black cotton.	500-750mm	Groundnut, Sorghum, Seteria, Paddy and cotton based	*Bb, Mb, Ti & Mm*
HIGH ALTITUDE & TRIBAL AREA (13.3% irrigated)	Northern parts of Srikakulam, Vizyanagaram, Visakhapatnam, East Godavari and Khammam.	NA	Above 1400m	Paddy and Pearl millet based	NA*

NA* - Not available

Bb *: Bandicota bengalenses* ***Rrw*** *: Rattus rattus wronghtoni*
Mb *: Mus booduga* ***Ti*** *: Tatera Indica and Mm : Millardia meltada*

districts. Rainfall is above 1400mm. Cropping system is paddy and pearl millet based. Only 13.3% of the area is irrigated. Major crops cultivated are rice, pearl millet, groundnut, finger millet, sesame, tuber crops, forestry and horticultural crops.

PEST STATUS AND DISTRIBUTION OF RODENTS

The cooperating centre of AICRP on Rodent control for Andhra Pradesh is functioning at the Agricultural Research Station, Maruteru since 1986. The emphasis of research is on rodent management in wet land paddy. Apart from paddy data

Table 2 : Rodent species distribution and composition in selected agro climatic ones of Andhra Pradesh

Agroclimatic zone	Place/ District	Associated crop/crops	Rodent species	Remarks
KRISHNA-GODAVARI ZONE	Godavari delta (Godavari dt.)	Irrigated rice	*Bb**, *Mb*	
	Tenali, Bapatla (Guntur dt.)	Rice and rice fallow pulses	*Bb*, *Mb**	*Bb* severe at maturity of rice fallow black gram
	Central delta (East Godavari dt.)	Coconut plantations Coconut nursery	*Rrw*, *Bb*, *Bi*, *Ti*, *Mb*	
	Jangareddygudem (West Godavari dt.)	Oil palm	*Bb*	
NORTH – COASTAL ZONE	Uddanam (Srikakulam dt.)	Coconut plantations Rice	*Rrw* *Bb* *Bb*	
SOUTHERN ZONE	Nellore dt. Kalahasti (Chittoor dt.)	Rice Rice	*Bb**, *Mb* *Bb*, *Mb**	
SCARCE RAIN FALL ZONE	Nandyal (Kurnool dt.) Chintalapatti & Medapuram (Anantapur dt.)	Rice Rice (Upland)	*Bb**, *Mb* *Bb**, *Mb*, *Ti*, *Mm*	
	Nandyal (Kurnool dt.)	Groundnut, Soybean, Green gram, Korra	*Mb* *, *Mm*, *Bb*	

Bb = *Bandicota bengalensis*; ***Mb*** = *Mus booduga*; ***Rrw*** = *Rattus rattus wroughtoni*;
Ti = *Tatera indica*; ***Bi*** = *Bandicota indica*; ***Mm*** = *Millardia meltada*
* Dominant species

Table 3 : Major pests and diseases of important crops of Andhra Pradesh

Crop	Insect and other pests	Diseases	Rodent pests
Rice	Yellow rice borer, rice gall midge, plant hoppers, green leaf hoppers, leaf folder, rice hispa, gundi bug, nematodes, cut worms, leaf mite, panicle mite.	Rice blast, Sheath blight, bacterial blight, stem rot, sheath rot, brown spot and false smut.	*Bb, Mb, Ti, Mm*
Millets	Shoot fly, stem borer, ear head bug, aphids, mites.	Grain smuts, leaf diseases, downy mildew.	NA*
Pulses	Pod borers, aphids, thrips	Fasarium wilt, powdery mildew, leaf spots, rust.	*Mb, Mm, Bb*
Sugar cane	Shoot borers, cane fly, scale insects, white fly, aphids, mealy bugs	Red rot, smut, grassy shoot wilt.	NA*
Coconut			*Rrw, Bb, Bi, Ti, Mb*

NA* - Not available
Bb *= Bandicota bengalensis;* ***Mb*** *= Mus booduga;* ***Rrw*** *= Rattus rattus wroughtoni;*
Ti *= Tatera indica;* ***Bi*** *= Bandicota indica;* ***Mm*** *= Millardia meltada*

has also been collected for fallow, pulses, coconut, oil palm, groundnut, soybean, green gram and korra (Table 2; Fig. 1). Following is the cropwise distribution of rodents in selected Agroclimatic zones of Andhra Pradesh.

(a) Rice (Tables 2 & 3): The rodent species affecting paddy yields were *B.bengalensis* and *M.booduga* in Godavari and Guntur districts of Krishna-Godavari, Southern zone and parts of scarce rainfall zone. Infestation of *B.bengalensis* was severe at maturity of rice and fallow black gram. In North-coastal zone only *B.bengalensis* damaged rice. The diversity of species increased slightly in parts of scarce rainfall area. In Kurnool district three species namely *M.booduga, M.meltada* and *B.bengalensis* occurred and in some other parts apart from these three, *T.indica* also occurred.

(b) Coconut plantation and nursery (Table 2): The crop in central delta of Krishna Godavari zone were infested by five species of rodents. These were *R.r.wroughtoni, B.bengalensis, B.indica, T.indica* and *M.booduga*. However in North coastal zone only two species damaged coconut viz., *R. rattus wroughtoni* and *B.bengalensis*.

(c) Oil palm (Table 2): The crop in west Godavari district of Krishna-Godavari zone was infested by *B.bengalensis*.

(d) Groundnut, Soybean, Greengram and Korra (Table 2): These crops in Nandyal district of scarce rainfall zone had three species of rodent pests namely *B.bengalensis, M.meltada* and *M.booduga*.

CONCLUSIONS

The research on species of rodents damaging wet land paddy has revealed *B.bengalensis* and *M.booduga* as major damage causing species in four out of the six agricultural zones of the state. In scarce rainfall area *M.meltada* and *T.indica* too become pests. It will be interesting to know the species composition in the two zones of Telangana. Floods occurred during August, 1986 followed by reported major rodent out break in Rabi 1986-87. Another major out break of rodents occurred in Rabi during 1996-97 and was attributed to cyclone in November 1996. Minor out breaks of rodents are reported to occur every 2-4 years.

II. ASSAM

Assam lies between 24° and 28° N latitudes and 89.5° and 96° E longitudes

LAND USE

Assam is divided into two distinct physiographic regions, the plains and the hills. The plains are represented by the Brahmaputra valley and Barak valley while the hilly area consists of a part of Barail and Meghalaya ranges. Soils of Assam are classified as Recent Riverine, Old Riverine, Old Mountain, Non-laterized and Laterized. Climate is characterised by hot & wet summers and dry & cool winters. The four seasons are pre monsoon (March-May), monsoon (June-August), post monsoon (September-November) and winter (December-February).

CROPPING SYSTEM

The state is by and large rain fed, rice based monocrop system. The three major crops of Assam are rice, tea and jute. Rice is grown as deep water crop, *Bao*; shallow water rice, *Asra* and rain fed autumn rice, *Ahu*. *Sali* is the transplanted rice while *Boro* rice is grown during summer or spring. Apart from rice, maize, millet and wheat are the other cereals cultivated. Black gram, moong, bean and lentil are grown during rabi. Rape and mustard are the oil seeds raised. Fruits grown include pine apple, banana, mango, papaya, citrus, litchi, guava and pomegranate. Coconut, areca nut and tea are the major plantation crops.

AGROCLIMATIC ZONES (Table 1; Fig. 1)

1. NORTH BANK PLAIN ZONE covers the north-eastern districts of Lakhimpur, Sonitpur and Darang. The soil types of this zone are old alluvial along the foot hills (Alfisols), old alluvial soils along old flood plains (Inceptisols) and new alluvial soil (Entisols) in recent flood plains. The average rainfall is 2650mm and the range is 1500-3000mm. The major crop is rice. Pulses and oil seeds are cultivated to a small extent. Horticultural crops include orange, pineapple, banana, coconut and areca nut.

2. UPPER BRAHMAPUTRA VALLEY ZONE lies in the south western side of the State includes the districts of Tinsukhia, Dibrugarh, Sibsagar, Jorhat and Golaghat. The zone is a rich source of oil and natural gas producing more than 80% of the state's oil. Coal fields are also found in this zone. The rainfall range is 1200-2347mm. Soils fall under the category of immature alluvium, mature ultisols and recent riverine alluvial (Entisol). The main crops of the area are rice, wheat, black gram, green gram, pea, lentil, potato, cucumber, colocasia, cole crops, rape, mustard and sesame. The commercial crops are jute and tea grown in large tracts of land and sugarcane. Horticultural crops are potato, orange, pineapple, banana, coconut and areca nut.

3. CENTRAL BRAHMAPUTRA VALLEY ZONE covers the district of Nawgong. Rainfall range is 1200-2000mm. Soils are mainly immature Entisols and mature Alfisols. Rice is the major crop. Oil seeds are grown extensively. Other important crops are jute, pulses, wheat and vegetables.

4. LOWER BRAHMAPUTRA VALLEY ZONE lies in the eastern part of the state. River Brahmaputra flows through this zone. The districts of Kokrajhar, Dhubri, Goalpara, Barpeta, Nalbari Kamrup and Pragjyotishpur come under this zone. The average rainfall is 1700mm. The soil types are Alfisols & Ultisols, Iceptisols & Alfisols, and Entisols. The major crops are rice, millet, jute, wheat, pulses, potato and oilseeds.

5. BARRACK VALLEY ZONE consists of Cachar and Karimganj districts. Flood is a frequent phenomenon in this zone. Rainfall range is 65-2500mm. Not much is known about the soil type. Based on limited sampling they seem to be similar to that of Brahmaputra valley. The entire central alluvial tract is rice mono-cropped area. Forest cover is 39%. Pine apple and sugarcane are the other crops.

6. HILL ZONE OF ASSAM comprises of Karbi Anglong and North Kachar hills. North Kachar hills are steep and high. Karbi Anglong hills are undulating and less high. Land in this hill area is classified as plain areas, hills with mild slopes and hills with steep slopes. Annual rainfall varies from 1000-2000mm. Soils are generally laterite, red loam and old alluvial. Rice is the most cultivated crop. Other crops include rapeseed, mustard, maize and sugarcane. Pineapple, banana, mango, papaya, litchi, guava, pomegranate are cultivated. Coffee and rubber have been introduced as plantation crops. Vegetables grown are mostly cole crops and indigenous vegetables.

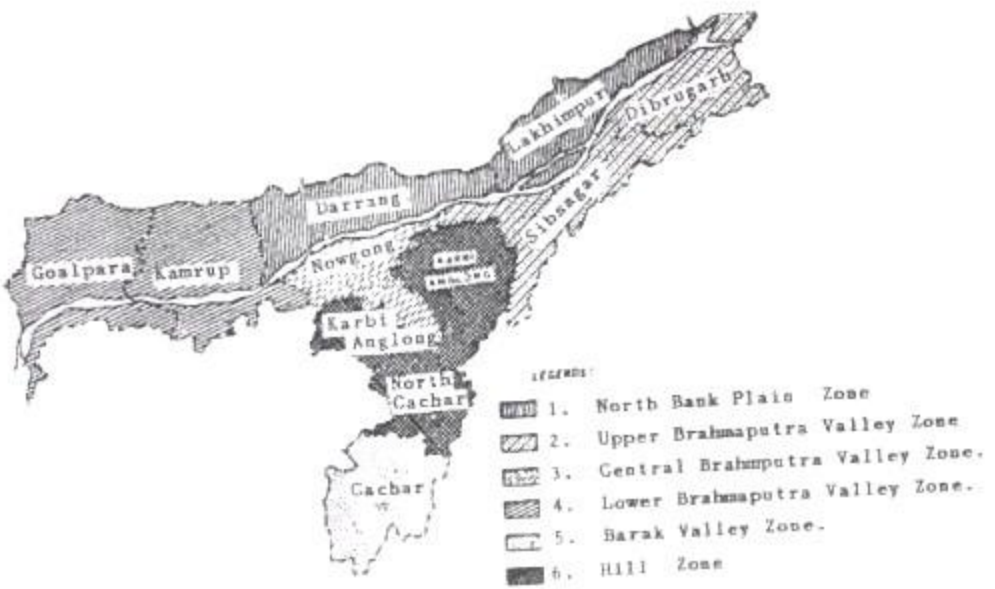


Fig. 1 Agro climatic zones of Assam

Table 1 : Agroclimatic zones, crop conditions and rodent pests of Assam

Zone	District/taluks	Soil type	Rainfall	Cropping system	Rodent pests (Species)
NORTH BANK PLAIN ZONE	Lakhimpur, Sonitpur and Darrang Dts.	Alfisols, Inceptisols Entisols	1500-3000mm	Rice major crop, pulses, oil seeds and fruits	NA*
UPPER BRAHMAPUTRA VALLEY ZONE	Tinsukhia, Dibrugarh, Sibsagar, Jorhat and Golaghat districts	Ultisols Entisols	1200-2347mm	Rice, wheat (winter), black gram, green gram, pea, lentil, potato, cucumber, cole crops, sugarcane, oil seeds	*Bbb, Bii, Mmc, Rr, Rs, Rn, Dl*
CENTRAL BRAHMAPTURA VALLEY ZONE	Nawgong	Entisols, Alfisols	1200-2000mm	Rice major crop Oilseeds extensively grown. Jute, pulses, wheat and vegetables	NA*
LOWER BRAHMAPUTRA VALLEY ZONE	Districts of Kokrajhar, Dhubri, Goalpura, Barpeta, Nalbari Kamrup & Pragjyothishpur	Alfisols Ultisols Iceptisols Entisols	1700mm (alfisols)	Rice, millets, jute, wheat, pulses, potato, oil seeds.	NA*
BARRACK VALLEY ZONE	Kachar and Karimganj districts	Not much known. Seem to be similar to that of Brahmaputra valley	65-2500mm	Rice mono cropping. Pine apple & sugarcane. Forest cover 39%	NA*
HILL ZONE OF ASSAM	Karbi Anglong and North Kachar hills	Laterite Red loam Old alluvial	1000-2000mm	Rice most cultivated Rape seed, mustard, maize, sugarcane, fruits, coffee, rubber	NA*

NA* - Not available

Bbb *: B. bengalensis bengalensis* ***Bii*** *: B. indica indica* ***Mmc*** *: Mus musulus castaneus*
Rr *: Rattus rattus* ***Rs*** *: R. sikkimensis* ***Rn*** *: R. nitidus* ***Dl*** *: Dremnomys lokriah*

PEST STATUS OF RODENTS AND THEIR DISTRIBUTION IN ASSAM

(a) Rice (Table 2): Amongst the four types of rice, namely *Sali, Ahu, Boro* and *Bao*, least damage was seen in *Boro* variety i.e. 1.99-5.39% and the species infesting were *B. bengalensis* and *M.booduga*. *Ahu* paddy was damaged in the range of 3.58 to 7.47%. *Sali* paddy was damaged in the range of 8.89 to 11.13% and had four species of rodents infesting the fields. They were *B.bengalensis > B.indica > M.booduga > R.sikkimensis*. The mean yield loss was 3.17%. In addition 1.4 kg material was hoarded/burrow (Anon, 2004a).

(b) Areca nut, fruits and vegetables (Table 3) Damage to areca nut as estimated by dropped nuts was 40.84% and was caused by the squirrel, *Dremnomys lokriah*. The ripe fruits of pummelo (*Citrus maxima*) were damaged by *D.lokriah* upto 40.12%. Amongst vegetables *B.bengalensis* caused 2.71 to 5.94% damage to pea and 5.3 to 7.91% damage to potato. There was no rodent damage to brinjal, cabbage, cauliflower, knol-khol and tomato.

(c) Species composition of rodents in fields around Jorhat (upper Brahmaputra valley zone) (Anon, 2003): Nine species belonging to family muridae namely *Bandicota bengalensis bengalensis* (Gray), *Bandicota indica indica* Bechstein), *Mus musculus castaneus* (Waterhouse), *Mus booduga*, *Rattus rattus* (Linnaus), *R.sikkimensis* (Hinton), *R.norvegicus* and *Dremomys lokriah* (Thomas) (Family Sciuidae) and one more unidentified species belonging to family sciuridae were reported from fields around Jorhat. Their relative abundance was *B.bengalensis* (33.42%) > *R.rttus* (22.5%) > *M.musculus* (11.5%) > *D.l.macmillani* (9.2%) > *R.sikkimensis* (7.4%) > *B.idica indica* (6.9%) > *M.booduga* (6.4%) > *R.norvegicus* (2.8%).

(d) Species composition of rodents infestingbamboo plantations in Manipur 2002-2003 (Anon, 2003) : Predominant speciesare White bellied rat, *Rattus rattus bullocki*, Manipur rat, *Rattus manipulus*, Inian mole rat, *Bandicota bengalensis*, and larger bandicoot rat, *Bandicota indica*.Other species found in Manipur are *Rattus rattus bruneusculus, Rattus rattustistae, Vandeleuria oleracea, Rattus bowersi, Hadromys humei, Mus cervicolor, Mus famulus cookie, Diomys crumpi, Cannomys badius badius* and *Rhizomys prinosus*.

Table 2 : Rodent damage to paddy during 2002-03 (NON, 2004a)

Paddy variety	Damage (% cut tillers inge)	Rodent species
Sali paddy	8.89 to 11.13	*Bb>Bi>Mb>Rs*
Ahu paddy	3.58 to 7.47	NA*
Boro paddy	1.99 to 5.39	*Bb>Mb*
Bao paddy	11.91 to 20.59	NA*
	3.17% YL	
	1.4kg/hoarded/burrow	

NA* - Not available

***Bb** : Bandicota bengalensis, **Bi** : Bandicota indica, **Mb** :Mus booduga, **Rs** : Rattus sikkimensis*

Table 3: Rodent damage to crops other than paddy (NON, 2003 & 2004a)

Crop	Damage (%) range	Species	Infestation rate (burrows/ha.)
Areca nut	40.84% (dropping nuts)	*D.lokriah*	NA*
Pummelo (*Citrus maxima*)	40.12% (Ripe fruit eaten)	*D.lokriah*	NA*
Pea	2.71 to 5.94	*B.bengalensis*	4.32
Potato	5.3 to 7.91	*B.bengalensis*	3.95

NA* - Not available

(e) Species composition of rodents in different habitats (Table 4): The predominant species in houses and rural stores were *R.rattus; M.musculus* and *B.bengalensis*. Godowns in urban areas were infested by *B.bengalensis* predominantly followed by *R.rattus, R.norvegicus* and *M.musculus*. Paddy fields and orchards had *B.bengalensis* as the major pest followed by *M.booduga* or *D.lokriah* (orchards). *B.indica* occurred in considerable proportion in these two habitats. Forests had only three species of rodents. They were *D.lokriah* > *B.bengalensis* > *B.indica*.

Table 4 : Species composition of rodents in different habitats of Jorhat district, Assam during 2003-04 (ANON, 2004a)

Habitat	Rodent species composition (% of total population)
Houses	*R.rattus* (35.56%)> *B.bengalensis* (25.56%)> *M.m.castaneus* (24.44%)>*R.sikkimensis* (14.44%)
Stores (rural)	*R.rattus* (41.86%)> *M.m.castaneus* (30.23%)> *B.bengalensis* (18.6%)> *D.lokraiah* (9.3%).
Godowns (urban)	*B.bengalensis* (42.37%)> *R.rattus* (22.03%)> *R.norvegicus* (18.64%) >*M.m.cataneus* (16.95%)
Kitchen garden	*B.bengalensis* (41.17%)>*R.ratttus* (29.41%)> *D.lokriah* (15.69%)>*M.booduga* (13.73%).
Paddy fields	*B.bengalensis* (43.75%)>*M.booduga* (25.8%)> *B.indica* (18.75%)> *R.sikkimensis* (12.5%).
Orchards	*B.bengalensis* (31.03%)>*D.lokriah* (18.97%)> *R.rattus* (17.24%)> *B.indica* (15.51%)> *M.booduga* (3.45%).
Forest areas	*D.lokriah* (48.15%)> *B.bengalensis* (29.63%)> *B.indica* (22.22%).

CONCLUSIONS

Although the centre was set up in 2002, considerable data has been collected from around Jorhat. *B.bengalensis, M.booduga* and *B.indica* were major pests of paddy, *B.bengalensis* damaged vegetables while the squirrel, D.lokraiah was a menace in orchards and forests. *R.rattus, B.bengalensis, M.musculus* and *R.norvegicus* were the predominant commensals. The bamboo plantations were infested by *B.b.bengalensis* (Gray), *B.i.indica* (Bechstein), *R.r.bullock* and *R.manipulus*. *B.indica, M.m.castaneus* (Waterhouse) *M.booduga, R.rattus* (Linnaeus), *R.sikkimensis* (Hinton), *R.norvegicus* (Berkentiout), *D.l.manmillari* (Thomas) (Family Sciuridae) and one more unidentified species belonging to family sciuridae were reported from fields around Jorhat. Their relative abundance was *B.bengalensis* (33.42%) > *R.rattus* (22.5%) > *M.musculus* (11.5%) > *D.l.macmillani* (9.2%) > *R.sikkimensis* (7.4%) > *B.i.indica* (6.9%) > *M.booduga* (6.4%) > *R.norvegicus* (2.8%).

III. GUJARAT

Situated in the west coast of India, Gujarat is spread over 196 lakh square km forming 6% of the county's landmass. The state is largely agrarian. The Soils of Gujarat belong to nine types namely, 1.Black soils, 2. Mixed red and black soils, 3. Residual sandy soils, 4. Alluvial soils, 5. Saline-alkaline soils, 6. Desert soils, 7. Laterite soils, 8. Hilly soils and 9. Forest soils.

CLIMATE

The extreme north region of the state has arid climate, the extreme south has sub-humid climate and rest of state has semi-arid climate. Rainfall is an average of 300mm in the western Kutch region and 1500mm average in the southern part. Monsoon is received during June-September. Temperature ranges from 12.5°c in January to 39.9°c in May. October is also quite hot. Nearly 50% of the land is cultivated of which 22.3% is irrigated, mostly by wells followed by canals. Tanks irrigate less than 2% area.

CROPS

The major crop of Gujarat is groundnut. The important cereals are bajra, sorghum, wheat. Pulses like green gram, pigeon pea, cowpea, bean and gram are grown to a small extent. Amongst commercial crops cotton and sugarcane are important. Coconut cultivation is restricted to Saurashtra region, so also vegetables. Very few vegetables are grown mostly brinjal and potato. Total cereals occupy about 38%, pulses 7% and oil seeds 24% of the gross cropped area. Other crops are grown in about 18% of the cultivated area.

AGROCLIMATIC ZONES (Table 1, Fig. 1)

There are eight agro-climatic Zones namely: South-Gujarat Heavy Rainfall Zone, South-Gujarat Zone, Middle Gujarat Zone, North Gujarat Zone, North-west Zone, North Saurashtra Zone, South Saurashtra Zone and Bhal and Coastal Zone. The physiographical features and crops of each zone are outlined below:

1. SOUTH GUJARAT HEAVY RAINFALL ZONE: This zone receives intensive rainfall ranging 1500-2200 mm mostly in the months of July and August. It is further divided into the Hilly and Non-hilly areas. The Hilly areas consist of the district of Dang and hilly areas of Valsad district with elevation varying from 106 to 1311m. The soil is clay, shallow and composed of fragmented rocks. The crops grown are Negli (ragi) *(Eleusine coracana)*, Kodra *(Paspalum scrobiculatum)*, Banti *(Echinochloa stagnina)*, Wari *(Panicum miliare)* and Cheno *(Panicum miliaeceum)*, rice, arhar, tubers and vegetables. The Non-hilly area comprises the plains of Valod district Valsad, Vyara, Songadh and Mahuva taluka of Surat district. Rainfall ranging

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

1000-1500mm is received during monsoon months. The soils are deep black and lie in the command area of Ukai, Kakrapura and Damanganga irrigation projects. Rice is the major crop with rabi cultivation of beans, wheat, gram, urad etc. Other crops grown are cotton, banana, mango, coconut, sapota etc.

The crop rotation followed is ragi-tur (finger millet-red gram) and black gram-tur in hilly areas while sugarcane-rice and rice-beans is the principal crop rotation in non-hilly areas.

2. SOUTH GUJARAT ZONE: It covers Navsari, Gandevi talukas of Valsad district, Karnrej, Choriashi, Nizai, Palsana, Bardoli, Mangroi and Mandvi talukas of Surat district and Ankleshwar, Valia, Jaghadia, Nanded, Dekdopada and Sagabara talukas of Bharuch district. Rainfall is medium at 1000-1500mm occurring during June-September. Soil is black, medium, heavy. Seventy five per cent of the area is rain fed. The principal crops are rice, sorghum, ragi, groundnut, sugarcane and pigeon pea. To a lesser extent kodra, cotton, chillies, gram and other pulses are grown. The crop rotation adapted is cotton, sorghum, paddy-beans, cotton-banana and sorghum- tur (red gram).

3. MIDDLE GUJARAT ZONE: The entire district of Panchamahal and Vadodra, Bharuch, Amod and Jambusar talukas of Bharuch district and part of Kheda district fall under this zone. Rainfall varies from 800-1000mm. The soil is sandy loamy, clay loam and clay. The major crops are rice, cotton, maize, pearl millet, tobacco, wheat, sorghum and groundnut. Minor crops include sesame, castor and chickpea. To some extent rape, mustard, potato and fruits like mango, papaya, banana and vegetables are grown.

4. NORTH GUJARAT ZONE: This zone covers the district of Kheda except part of Camby, Matar talukas, entire Sabarkantha district, Mehsana district excluding Sami and Harij talukas, Dehgam, Daskroi and Sanand talukas of Ahmedabad. The region is arid and semiarid with erratic rainfall in the range of 500-1014mm. The soils of this zone are broadly classified into six groups namely medium black, alluvial sandy to sandy loam, alluvial sandy loam to sandy clay loam, hilly soils, residual sandy soils and saline alkaline soils. The major crops cultivated are pearl millet, cotton, sorghum, maize, castor, pulses, wheat, rape and mustard. The minor crops grown are rice, groundnut, sesame, gram and cumin.

5. NORTH WEST ZONE: The area under this zone comprises of Malia taluka of Rajkot, Halwad, Dhrangahdhra, Dasada talukas of Surendranagar, Sami, Harij, Chanasma talukas of Mehsana district, Santalpur, Radhanpur, Kankeraj, Diodar, Vav, Tharad talukas of Banaskantha district and Viramgram taluka of Ahmedabad district. Rainfall is scanty varying from 250-500mm. Soil type is residual sandy and alluvial sandy. Major crops grown are pearl millet, sorghum, groundnut, cotton and pulses. To a lesser extent sesame, castor and wheat are also cultivated. Cultivation of rice, barley and gram is there but insignificant.

6. NORTH SAURASHTRA ZONE: This zone is constituted by entire Jamnagar district, Paddhari, Lodhika, Jasdam, Rajkot, Vakaner and Morvi talukas of Rajkot district, Ghadhada, Umrala Botad talukas of Bhavanagar district. Agriculture is dependent on 500-725 mm of southwest monsoon, which is erratic. Soil is medium black, residual sandy and coastal saline type. Groundnut is the principal crop being cultivated in more than 50% of the cropped area. Other important crops are cotton, pearl millet and sorghum. Cultivation of castor and pulses is minimal.

7. SOUTH SAURASHTRA ZONE: Entire Junagadh district, Shihor, Ghogha, Gariadhar, Palitana, Talaja, Mahuva, Savarkundla talukas of Bhavnagar district, Dhari, Kodinar, Rajula, Jafrabad, Khambha, Amreli, Babra, Liliya, Lathi, Kukarav talukas of Amreli district, Jetpur, Gondal, Dhoraji and Upleta talukas of Rajkot district come under this zone. Rainfall varies from 500-970mm. The soil types are: medium black, shallow black, mixed red, black and coastal alluvial. Groundnut is cultivated in 65% of the area under cropping. The other major crops are pearl millet, wheat, sorghum, sugarcane, cotton and gram. Rice, maize, rape & mustard and pulses are cultivated in small areas. The economy of this region mainly depends on groundnut.

8. BHAL AND COASTAL ZONE: The zone comprises of Olpad taluka of Surat district, Harisot and Wagra talukas of Bharuch district, Cambay taluka of Kheda district, Dhokla, Dhanduka talukas of Ahmedabad district, Vallabhipur, Bhavnagar talukas of Bhavanagar district and Limdi taluka of Surendranagar district. The rainfall range is 550-758mm. Soil is medium black, coastal alluvial and saline alkaline. The major crops are rain fed wheat, cotton, sorghum, and gram. Small amounts of paddy and groundnut are also cultivated.

Table 1: Details of Agroclimatic zones and crop conditions in Gujarat

Zone	Districts and Taluks	Soil type	Rainfall (mm)	Crops	Rodent pest species
SOUTH GUJARAT HEAVY RAIN FALL AREA (canal & well irrigated)	Dang Dt., Valsad Dt. except Navasari & Gondevi tlks & Valod, Vyara, Songadh & Mahuva tlks of Surat Dt.	Deep black Patches of coastal alluvial, Laterite & Med. black	1500-2200 Jul - Aug	Rice, Sorghum, Ragi, Pigeon pea, Groundnut, Sugarcane	NA*
SOUTH GUJARAT (canal & well irrigated)	Navasari & Gondevi tlks of Valsad, Kamrej, Chonashi, Nizal, Palsana, Bardoli, Mangro, Mandvi tlks of Surat, Ankleshwar, Valia, Jaghadia, Nanded, Dekdopada and Sagabara tlks of Bharuch Dt.	Black medium, Heavy clayey	1000-1500 June-Sept.	Sorghum, Rice, Ragi, Groundnut, Sugarcane & Pigeon Pea	NA*
MIDDLE GUJARAT (canal & well irrigated)	Entire Panchamahal and Vadadora Dt., Bharuch, Amod & Jambusar tlks of Bharuch Dt. and Parts of Kheda Dt.	Sandy loam, Clay loam, Clay	800-1000	Rice, Cotton, Maize, Pearl millet, Tobacco, Wheat, Sorghum and Groundnut	NA*
NORTH GUJARAT ZONE (rainfed)	Whole of Kheda dt. except part of Camby & Matar tlks, Whole of Sabarkantha Dt., Dehgam, Deskroi & Sanand tlks of Ahmedabad., Deesa, Dhanera, Palanpura, Danta & Vadgam taluks of Banaskantha Dt., Whole of Mehsana Dt. except Sami & Harij tlks	Med. Black, Alluvial, sandy to Sandy loam, Alluvial Sandy loam to sandy clay loam, Hilly soil, Residual sandy soil.	500-840	Pearl Millet, Sorghum, Maize, Groundnut, Cotton, Pulses, Castor, Wheat, Rape & Mustard	*Ti, Mh, Bb, Mm*
NORTH WEST ARID ZONE (rainfed)	Malia tlk of Rajkot Dt., Halvad, Dhangadhara & Dasada taluks of Surendranagar Dt., Sami, Harij & Chanasma tlks of Mehsana Dt., Santalpur, Radhanpur, Kankeraj, Diodar, Vav and Tharad tlks of Banaskantha Dt., Viramgram tlk of Ahmedabad Dt.	Residual sandy, Alluvial sandy	300-640	Pearl millet, Sorghum, Groundnut, Cotton, Pulses	*Mh, Ti*
NORTH SAURASHTRA ZONE (rainfed, well irrigated)	Whole of Jamnagar Dt., Paddhari, Lodhika, Jasdan, Rajkot, Vakaner & Morvi tlks of Rajkot dt., Gadhada, Umrala & Botad tlks of Saurashtra Dt.	Med. Black, Residual Sandy, Coastal-saline	500-725	Groundnut, Cotton, Pearl-millet, Sorghum	*Ti, Mh, Bb, Mm, Rr*
SOUTH SAURASHTRA ZONE (rainfed, well & very little canal irrigation)	Entire Junagadh Dt., Shihor, Ghogha, Gariadhar, Palitana, Talaja, Mahuva & Savarkundla tlks of Bhavnagar Dt., Dhari, Kodinar, Rajula, Jafrabad, Khambha, Amreli, Babra, Lilya, Kukarav tlks of Amreli Dt., Jetpur, Gondal, Dhoraji & Upleta tlks of Rajkot Dt.	Med. Black, Shallow black, Mixed red Black Coastal alluvial	500-970	Groundnut, Pearl millet, Wheat, Sorghum, Sugarcane, Cotton, Gram	*Bb, Mm, Ti*
BHAL & COASTAL AREA (rainfed)	Olpad taluk of Surat Dt., Hansot & Wagra tlks of Bharuch Dt., Cambay tlk of Kheda Dt., Dholka & Dhanduka tlks of Ahmedabad Dt., Vallabhipur & Bhavnagar tlks of Bhavanagar & Limdi tlk of Surendranagar Dt.	Med. Black, Coastal-alluvial, Saline-alkali	550-758	Rice, Pearl millet, Cotton, Sorghum, Wheat	*Ti, Bb, Mm*

NA*-Not available

PEST STATUS OF RODENTS AND DAMAGE TO CULTIVATED CROPS (Tables 2 & 3)

Studies under All India Co-ordinated Research Project on Rodent Control from 1988-2002 revealed the following extent of damage to standing crops by rodent pests: Groundnut: 4-12%, Cotton: 0-6%, Bajra: 3-12%, Sorghum: 4-11%, Pulses: 4-11%, Wheat: 3-21%, Coconut: 0-11%, Brinjal: 4-10%, Potato: 0-7%, Tomato: 0-18%, Cucurbits: 5-10%, Carrot: 9-11%, Sweet potato: 3-9%, Lucern: 3-16% and chilly: 2-6%.

A comparison of crop losses to insects, diseases and rodents (Table 2) indicates that insects and diseases are more damaging than rodents in groundnut, cotton, bajra, sorghum, pulses, coconuts, sugarcane and vegetables. The extent of rodent damage outweighed that of diseases in bajra, pulses, coconut and brinjal. Rodents caused more yield loss than insects and diseases put together in wheat.

THE CROPWISE INFESTATION OF RODENTS IN GUJARAT IS AS FOLLOWS

(a) Groundnut: Groundnut is cultivated during kharif in South and north Saurashtra, Bhal & Coastal zone and North Gujarat dry zone. Only in South Saurashtra summer groundnut was grown. The range of rodent damage was 4-12 except during 1975-76 and 1989-90 when there was an explosion in rodent population. The intensity of rodent damage in field crops increased from kharif 1988 to rabi 1989-90 and reached as much as 85.42% in an isolated groundnut field surrounded by barren/ fallow land during the summer of 1989. Because of the heavy damage due to rodents in rabi crops of 1989-90, farmers avoided sowing summer groundnut during 1990 in most of the groundnut growing areas of Saurashtra region. *B.bengalensis* was the major species damaging groundnut in most of South and North Saurashtra followed by *M.meltada* in both kharif and summer. In some talukas *T.indica* was the major or second most abundant species. The same predominance of *T.indica* was seen in Bhal and coastal as well as North Gujarat Dry zones. *M.hurriane* was seen only in north Gujarat dry zone.

(b) Bajra: It is cultivated in South and North Saurashtra as well as in Bhal and Coastal area. *B.bengalensis* was the major pest followed by *T.indica and M.meltada* in South Saurashtra. Sometimes *T.indica* emerged as the predominant species. The same trend was seen in North Saurashtra. However in Bhal and coastal zone *T.indica* was the major species followed by lesser bandicoots and metads.

(c) Sorghum: In South and North Saurashtra *B.bengalensis* was the major species followed by metads or gerbils. However in some talukas gerbils were the most abundant species followed by bandicoots and metads. Similar species composition was seen in Bhal and Coastal areas, as well as North Gujarat Dry Zone.

(d) Wheat: The crop grown during rabi in South and North Saurashtra, Bhal and Coastal zone, during summer in North Saurashtra. Lesser bandicoot was the major pest. In some talukas gerbils were predominant and few metads were found more than the other two species.

Table 2 : Major crop depredators and diseases of crops in Gujarat

Sl. No.	Crops	Insects		Pathogens		Rodents	
		(%) Dam.	Category	(%) Dam.	Diseases	% Dam	Species
1	Groundnut	15-30	Aphid, Jassid, *Spodoptera Helicoverpa*, Whitegrub	15-20	Tikka, Stem rot	4-12	*Bb, Ti, Mm, Mh*
2	Cotton	10-25	Aphid, Jassid, Spotted bollworm, Spodoptera, Helicoverpa	5-15	Bacterial blight, Wilt and root wilt	0-6	*Bb, Ti, Mm, Mh*
3	Bajra	10-20	Shoot fly, stem bores	5-10	Downey mildew Ergot	3-12	*Bb, Ti, Mm*
4	Sorghum	10-25	Stem borer	5-8	Sugary disease, Head mold	4-11	*Bb, Ti, Mm, Mh*
5	Pulses	15-30	Pod borer	3-5	Wilt root rot	4-11	*Bb, Ti, Mm, Mh*
6	Wheat	5-8	*Helicoverpa*	5-8	Leaf blight	3-21	*Bb, Ti, Mm*
7	Coconut	10-40	Leaf eating caterpiller	5-7	Bud rot	0-11	*Rr*
8	Brinjal	15-25	Shoot and fruit borer	2-3	Root rot	4-10	*Bb, Mm, Ti*
9	Potato	10-20	Tuber moth	5-15	Early blight, Tuber skin spot	0-7	*Ti, Mh, Bb, Mm*
10	Sugarcane	15-30	Stemborer, scale insect, whitefly	10-15	Wilt	0-7	*Bb, Ti, Mm*
11	Tomato					6-18	*Bb>Mm>Ti*
12	Cucurbits					5-10	*Bb>Mm>Ti* *Ti>Mh>Bb>Mm*
13	Carrot					9-11	*Bb>Mm>Ti*
14	Sweet potato					3-9	*Bb>Mm>Ti*
15	Lucern					3-16	*Bb>Ti>Mm*
16	Chilli					2-6	*Bb>Mm>Ti*

(e) Pulses: The pulses are cultivated during all the three seasons in a year i.e. kharif, rabi and summer in South Saurashtra only. *B.bengalensis* was the major species except in few talukas where *T.indica* was more in numbers. The other noticeable species was *M.meltada*. In North Saurashtra and Bhal and Coastal areas pulses were grown only during rabi. *B.bengalensis*, *T.indica* and *M.meltada* infested these fields with bandicoots dominant in some talukas, gerbils in some other talukas and metads in still other talukas. In North Gujarat Dry Zone pulses were raised only in kharif. The desert gerbil *Meriones hurriane* was seen together with the Indian gerbil, *T.indica*. The two gerbil species were predominant in this zone followed by lesser bandicoots and metads.

(f) Sugarcane : It is cultivated during kharif and rabi in North and South Saurashtra, in Bhal and Coastal zone and North West Arid Zone. *B.bengalensis* was the major

Table 3 : Rodent damage to major crops in Gujarat and species involved

Crop	Zone	*Kharif*		*Rabi*		Summer	
		% Dam (range)	Rodent Sp. Composition	% Dam (range)	Rodent Sp. Composition.	% Dam. (range)	Rodent sp. composition
Groundnut	S. Saurashtra	4-7	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*	-	-	3-12	*Bb>Mm>Ti Ti>Bb>Mm*
	N. Saurashtra	4-10	*-do-*	-	-	-	-
	Bhal & Coastal	6-12	*Ti>Bb>Mm*	-	-	-	-
	N.Gujarat Dry	4-5	*Ti>Mh>Bb>Mm*	-	-	-	-
Bajra	S. Saurashtra	3-12	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*	2-5	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*	2-5	*Bb>Mm>Ti Ti>Bb>Mm*
	N. Saurashtra	4-10	*-do-*	-	-	-	-
	Bhal & Coastal	4-11	*Ti>Bb>Mm*	-	-	-	-
Sorghum	S. Saurashtra	4-11	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*	-	-	4-7	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*
	N. Saurashtra	3-11	*-do-*	-	-	-	-
	Bhal & Coastal	0-9	*Ti>Bb>Mm*	-	-	-	-
	N.Gujarat Dry	4-5	*Ti>Mh>Bb>Mm*	-	-	-	-
Wheat	S. Saurashtra	-	-	3-21	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*	-	-
	N. Saurashtra	-	-	2-11	*Bb>Mm>Ti Ti>Bb>Mm Mm>Bb*	0-5	*Bb>Ti*
	Bhal & Coastal	-	-	4-5	*Bb>Ti>Mm*	-	-
Pulses	S. Saurashtra	4-8	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*	5-9	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*	4-6	*Bb>Mm>Ti Ti>Bb>Mm*
	N. Saurashtra	-	-	2-11	*Bb>Mm>Ti Ti>Bb>Mm Mm>Bb*	0-5	*Bb>Ti*
	Bhal & Coastal	-	-	4-6	*Bb>Ti>Mm*	-	-
	N.Gujarat Dry	0-5	*Ti>Mh>Bb>Mm*	-	-	-	-
Sugarcane	S. Saurashtra	5-7	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*	6-8	*Bb>Mm>Ti Bb>Ti>Mm Ti>Bb>Mm*		
	N. Saurashtra	-	-	0-5	*Bb>Mm>Ti Ti>Bb>Mm Mm>Bb*		
	Bhal & Coastal	-	-	0-5	*Bb>Ti>Mm*		
	North west arid	-	-	0-5	*Mh>Ti>Ti Ti>Mm>Bb Bb>Ti>Mm*		

Crop	Zone	Kharif		Rabi		Summer	
		% Dam (range)	Rodent Sp. Composition	% Dam (range)	Rodent Sp. Composition	% Dam (range)	Rodent sp. composition
Cotton	S. Saurashtra	4-6	*Bb>Mm>Ti* *Bb>Ti>Mm* *Ti>Bb>Mm*	2-6	*Bb>Mm>Ti* *Bb>Ti>Mm* *Ti>Bb>Mm*	-	-
	N. Saurashtra	3-6	*-do-*	2-6	*Bb>Mm>Ti* *Ti>Bb>Mm* *Mm>Bb*	-	-
-	Bhal & Coastal	0-6	*Ti>Bb>Mm* *Bb>Ti>Mm*	-	-	-	-
	N.Gujarat Dry	-	-	0-6	*Ti>Bb>Mm*	-	-
	North west arid	-	-	3-5	*Mh>Ti* *Ti>Mm>Bb* *Bb>Ti>Mm*	-	-
Coconut	S. Saurashtra	7-11	*Rr*	-	-	6-9	*Rr*
	N. Saurashtra	0-6	*Rr*	-	-	-	-
VEGETABLES							
Tomato	S. Saurashtra	0-6	*Bb>Mm>Ti*	9-18	*Bb>Mm>Ti*	-	-
Brinjal	S. Saurashtra	5-10	*Bb>Mm>Ti*	4-5	*-do-*	-	-
Chilly	S. Saurashtra	4-6	*Bb>Mm>Ti*	3-12	*-do-*	-	-
	N. Saurashtra	2-5	*Bb>Mm>Ti*	-	-	0-6	*Bb>Ti>Mm*
Cucurbits	S. Saurashtra	5-10	*Bb>Mm>Ti*	-	-		
	N.Gujarat Dry	5-6	*Ti>Mh>Bb>Mm*	-	-		
Potato	N.Gujarat Dry	-	-	0-7	*Ti>Mh>Bb>Mm*	-	-
Carrot	S. Saurashtra	-	-	9-11	*Bb>Mm>Ti*	-	-
Lucer	S.Saurashtra	-	-	-	-	3-16	*Bb>Ti>Mm*
Sweet potato	S.Saurashtra	-	-	-	-	3-9	*Bb>Mm>Ti*

species except a few talukas where *T.indica* was predominant. *M.meltada* was predominant in some parts of North Saurashtra. Only these three species were found in Saurashtra and Coastal areas. But in North West dry zone two species of gerbils namely *M.hurrianae* and *T.indica* were predominant except a few pockets where *B.bengalensis* was more in numbers. *M.meltada* also occurred but in comparatively smaller numbers.

(g) Cotton : Cotton is cultivated during kharif and summer in South and North Saurashtra, during kharif in Bhal and Coastal zone, during summer in North Gujarat Dry and North West Arid zone. *B.bengalensis* followed by metads/gerbils was the species composition in all the zones except North West arid zone. In a few talukas in these zones gerbil became predominant followed by lesser bandicoots/metads. In North West arid zone *M.hurriane* and *T.indica* were dominant except in some talukas where *B.bengalensis* was predominant. The other species found occurring was *M.meltada*.

Table 4 : Relative abundance of rodent species in various crops grown in different agro-climatic zones of Gujarat

Zone	Crops	Rodent species complex
NORTH GUJARAT DRY ZONE	Groundnut, Sorghum, Pulses, Cucurbits, Potato.	*T.indica>M.hurrianae> B.bengalensis>M.meltada*
NORTH WEST ARID ZONE	Sugarcane, Cotton.	*M.hurrianae>T.indica*
NORTH SAURASHTRA ZONE	Groundnut, Bajra, Sorghum, Wheat, Pulses, Sugarcane, Cotton, Chilly	*T.indica>M.hurrianae> B.bengalensis>M.meltada* or *T.indica>B.bengalensis* or *M.meltada>B.bengalensis*
	Coconut	*R.rattus*
SOUTH SAURASHTRA ZONE	Groundnut, Bajra, Sorghum, Pulses, Sugarcane, Cotton, Wheat, Tomato, Brinjal, Cucurbits, Carrot, Chilly and Sweet potato	*B.bengalensis>M.meltada> T.indica*
	Coconut	*R. rattus*
BHAL & COASTAL ZONE	Groundnut, Bajra, Sorghum, Cotton.	*T.indica>B.bengalensis> M.meltada*

(h) Coconut : The coconut plantations are raised only in South and North Saurashtra. *R.rattus* was the only species infesting coconut fields.

(i) Vegetables: Tomato, brinjal and chilly were grown during kharif and rabi in South Saurashtra while chilli was grown both during kharif and summer in North Saurashtra. These crops and cucurbits in Saurashtra were infested by three species of rodents whose order of occurrence was *B.bengalensis > M.meltada > T.indica*. However the cucurbit fields in North Gujarat were predominantly infested by *T.indica* and *M.hurriane* followed by lesser bandicoots and metads. The same species complex of *T. indica > M hurrianae > B. bengalensis > M. meltada* was found in the potato fields of North Gujarat. The species composition of *B. bengalensis > M. meltada > T. indica* was seen in carrot fields during rabi and sweet potato fields during summer in South Saurashtra. The lucerne fields in South Saurashtra were predominantly infested by *B.bengalensis* followed by *T.indica* and *M.meltada*. Sweet potato grown during summer in South Saurashtra was infested by *B. bengalensis > M. meltada > T. indica*.

To sum up there are eight rodent species infesting the crop fields of Gujarat (Fig. 1). Basically it is four combinations namely *B.bengalensis-M.meltada - T.indica, T.indica - M.hurrianae - B.bengalensis - M.meltada, B.bengalensis-T.indica-M.meltada and M.hurrianae-T.indica. R.rattus* occurs as the sole species in coconut grown in South and North Saurashtra. In parts of North Saurashtra *B.bengalensis, T.indica* and *M.meltada* occur in two species composition specially in wheat, pulses, sugarcane and cotton. A combination of gerbils i.e. *M.hurrianae-T.indica* is seen only in sugarcane and cotton grown in North West arid zone. Most of the crops grown in South and North Saurashtra, Bhal and Coastal zone, North Gujarat Dry

and North West arid zone have different combinations of *B.bengalensis*, *T.indica*, and *M.meltada*. North Gujarat dry zone is distinct by harbouring two gerbil species namely *M.hurrianae* and *T.indica* along with *B.bengalensis* and *M.meltada* in groundnut, pulses, cucurbits and potato.

CONCLUSIONS

In the zones and crops studied both species of field mice namely, *Mus booduga* and *M.platythrix* were absent. Similarly the hairy footed gerbils, *Gerbillus gleadowii* commonly found on sand dunes in western Rajasthan and the Indian bush rat, and *Golunda elioti* were not seen. It can be concluded that the predominant rodent pests of Gujarat are *B.bengalensis*, *M.meltada* and *T.indica*. Gerbils are predominant in arid and dry regions namely North West arid zone and North Gujarat Dry Zone. *R.rattus* is restricted to coconut plantations.

So far data on species composition has been recorded for five out of the eight zones namely, South Saurashtra, North Saurashtra, Bhal and Coastal zone, North Gujarat dry zone and Northwest arid zone. Studies are to be carried out for South Gujarat heavy rainfall zone, South Gujarat canal and well irrigated zone and Middle Gujarat canal and well irrigated zone.

IV. HIMACHAL PRADESH

Himachal Pradesh is a hilly state with its altitude ranging from 350m to 6975m above mean sea level (MSL). Geographically Himachal Pradesh is located in the Himalayan Mountain between 30° 24' 40'' N and 30° 12' 40'' N latitude and 75° 04' 55'' E and 70° 04' 20'' E longitude. Physiographically the state can be divided into Greater Himalaya (altitude range 5000-6500m above MSL), Outer Himalaya (average height of 6000m above MSL) and Lesser Himalaya (altitude range 4000-5000m above MSL) lying between Greater Himalaya and Outer Himalaya.

PHYSIOGRAPHY AND AGRO CLIMATE

The state has extreme climates ranging from hot summer to cold winter. Heavy snow fall characterizes northern high altitude ranges which often remain under snow for about six months. In contrast the low hills of Una and Hamirpur districts are warm with monthly maximum temperature of 37-38°C and monthly minimum around 10°C. Milder climate characterizes other parts of the state.

The average rainfall is 1150mm ranging 1500-1750mm in the outer Himalayas and 750-1000 mm in the inner Himalayas. Rainfall is low in Lahaul-Spiti and Kinnaur due to rain shadow effect. In fact Spiti is in cold desert tract, receiving less than 50mm rainfall. Most of the rainfall is received during June to September with occasional rains in winter.

LAND USE

Cropping intensity is highest in Himachal Pradesh compared to other states in the Western Himalayan tract. Maize and rice are important kharif crops while wheat and barley are grown during rabi. Tropical and temperate fruits are extensively grown. Apple is a dominant fruit crop forming 80 per cent of the total fruit production of the state. The other temperate fruits grown are: peach, plum, apricot, pear, almond and walnut. The state is known as the APPLE STATE OF INDIA. The yield and returns of fruit crops is higher than cereal crops. As a result the agricultural economy of the state is different from the other states and is dominated by horticultural crops and forest products. Vegetable crops also contribute significantly to the state's economy. These include all season vegetables like cabbage, cauliflower, tomato, radish, peas, cucumber, capsicum etc. Seed production of vegetables like cauliflower, cabbage, radish and chicore are also significant. Potato is an important cash crop of Himachal Pradesh being cultivated as summer crop under long day conditions at 1500-2700m above MSL and in the cold desert areas at an elevation of 3000m and above. Around two-thirds of potato cultivated is for seed production. Forest is also a good source of income providing timber, fuel, fodder etc. in addition to conserving soil and maintaining ecological balance. Wheat and maize are the important cereals followed by rice. Rice and wheat are largely irrigated.

CROPPING SYSTEMS

The popular cropping system is a two year rotation of potato-wheat-maize-fallow in the districts of Shimla, Mandi, Kulu and Sirmour. In Kinnaur the rotation is potato-buckwheat-French bean-grain-barley. In Hamirpur, Bilaspur, Una and Solan, rice-wheat, maize-wheat, potato-wheat, potato-potato is the crop rotation pattern. Cabbage cultivation has increased tremendously, often replacing maize.

AGRO CLIMATIC ZONES

Based on altitude, temperature, soil type and cropping sequence, the state is divided into four Agroclimatic zones (Fig. 1 and Table 1).

1. SUB TROPICAL, SUB-MONTANE AND LOW HILLS (Upto 614m above MSL): Districts Una, Bilaspur, Hamirpur and parts of Sirmour, Solan, Kangra and Chamba come under this zone. Soil is shallow, light textured and low in fertility. The seven different farming systems are: rainfed hilly tract, rainfed valley tract, irrigated valley tract, irrigated hilly tract, water logged area, sandy soil tract and flood

Fig. 1: Agroclimatic zones of Himachal Pradesh

Table 1 : Agroclimatic zones and crop conditions of Himachal Pradesh

Zone	Districts & Taluks	Soil type	Rainfall (mm)	Attitude	Crops	Rodent pests (species)
SUBTROPICAL SUB-MONTANE AND LOW HILLS	Una, Bilaspur, Hamirpur Dts and parts of Sirmour, Solan, Kangra and Chamba dts.	Shallow, light textured, loamy sand to sandy loam.	1100mm(av) (July-Sept)	614m and above msl.	Rice, Wheat, Sugarcane, Citrus, Mango, Litchi, Guava, deciduous forest, Vegetables, Oilseeds, Barley.	*Bb, Rr* (commensal), *Ge, Mm, Mb, Mp, Fp, Hi, Ti.*
SUB TEMPERATE SUB HUMID MID HILLS (Natural irrigation & rains)	Palampur & Kangra tlks of Kangra Dt., parts of Mandi, Solan, Kullu, Sirmaur Dts., and Rampur tlks of Simla	Loamy to clay loam.	800-1300mm	615-1800m above msl.	Rice, Wheat, *Arhar*, Seasame, Temperate fruits, pulses, oilseeds, potato Citrus, Vegetables, Himalayan temperate forests.	*Bb, Mm, Rr* (commensal), *Ge, Mm, Mb, Mp, Fp, Hi, Ti.*
WET TEMPERATE HIGH HILLS	Parts of Kullu, Solan, Chamba, Mandi, Kangra and Sirmour Dts., Simla except Ramut *tehsil.*	Silty loam to clay loam.	1380-1500mm (July-Sept)	1500-6000 above msl.	Maize, Rice, Oilseeds, Pulses, Rajmah, Soybean, Barley, Bee keeping, Apple, Pear, Plum, Peach, Apricot, Chestnut, Vegetables.	*Bb, Rr* (commensal), *Mm, Mb* (upto 2000m) *Hi* (upto 1200m)
DRY TEMPERATE HIGH HILLS & COLD DESERT	Districts of Kinnaur, Lahul, Spiti and parts of Chamba Dt.	Sandy loam	250mm and below	2000-7000m msl	Barley, Maize, Pulses, Potato, Minor millets, Hops, Cumin, Saffron, Apples, Nuts, Chilgoza, Neoza pine, Cabbage seed, Sugar beet, Chicory, Agro forestry.	*Bb, Rr* (commensal), *Mm.*

prone area of the reservoir bank. The zone receives an average of 1100mm rainfall.

Wheat and maize are the predominant cereal crops grown followed by rice, barley, black gram, beans and oil seeds viz., soybean, mustard and linseed. Potato is the major vegetable. Other vegetables grown are cabbage, radish, French bean, tomato, peas, chillies and onion. The major fruits grown are mango, litchi, guava, ber, citrus, and pomegranate. Peach and plum are grown to a lesser extent. Considerable acreage is under forestry, grass lands and pastures.

2. SUB-TEMPERATE, SUB HUMID MID HILLS (615-1800m above MSL) : This zone comprises of Palampur and Kangra tehsils of district Kangra, Rampur tehsil of district Shimla and parts of Mandi, Solan, Kullu, and Sirmaur districts. The soil texture varies from loamy to clay loam. The range of rainfall is 800-1300mm.

Wheat is the most important crop followed closely by maize, and rice to a lesser extent. The other crops are barley and pulses like rajmah, black gram and green gram. Oil seeds grown are mustard, linseed and soybean. Potato cultivation is extensive. Main vegetables are cabbage, radish, French bean, tomato, peas, chillies and onion. Large areas are used for cultivating apple, plum, peach, walnut, almond, apricot and citrus fruits. Forestry, pasture and grasslands are also significant. More than 80% of the area is rainfed. Maize-pea-wheat is one of the most widely employed rotation pattern.

3. WET TEMPERATE HIGH HILLS (1500-6000m above MSL): This zone consists of only mountainous tracts. It comprises of Shimla, (except Rampur tehsil), parts of Kullu, Solan, Chamba, Mandi, Kangra and Sirmaur districts. The soil is salty loam to clayey loam, deep and neutral in reaction. The range of rainfall is 1380-1500mm. From November to March snowfall and ground frost are experienced. The agro climatic conditions being ideally suited for temperate fruits, apple forms 90% of total fruit production. Fruits like apple, pear, cherry, walnut, chilgoza, plum, apricots and vegetables such as cauliflower, cabbage, capsicum and peas are grown in three of the four farming situations namely, stone fruit area of Mashobra, temperate fruit area of Kotkhai and high hills of Chamba. It is only in the Medium hill area of Katrain that cereals mainly rice, maize, and rajmah are grown along with fruits and vegetables.

4. DRY TEMPERATE HIGH HILLS AND COLD DESERT (2000-7000m above MSL): This zone comprises the districts of Kinnaur, Lahul, Spiti and parts of Chamba. With elevations being 2000m above MSL, the zone remains covered with snow from November to March. The rainfall is scanty at 25-250mm. Soil is sandy loam and neutral to alkaline. Only 2% of the total cropped area of the state belongs to this zone. Barley, maize, minor millets, potato, spices, sugar beet, fruits and chicory are grown.

PEST STATUS OF RODENTS (Tables 2-4)

A comparison of extent of damagecaused by insects and rodents in horticultural crops revealed that the latter :ause considerable losses (Table 2). Often they cause more damage than insecs especially in cabbage, cauliflower and apple. Damage to pea. tomato, peach nd peanut is also significant.

Table 2 : Damage caused by insect pests and rodentto magor crops.

Host	Per cent damage	
	Insects	Rodents
Pea	5-7	3-8
Cabbage	12-15	3-90
Cauliflower	12-15	6-21
Tomato	15-30	2-7
Apple	20	17-40
Peach	10-15	2-7
Plum	5-7	1-2
Peanut	-	2-7

The Solan centre of All India Co-ordinatd Research Project on Rodent Control was set up in 1987 at the Dr. Y.S. Parmar Jniversity of Horticulture and forestry to carry out studies on rodent pest manaement in horticultural crops and the data generated is as follows:

(a) Cereals (Table 3) : Paddy, wheat and mize were the crops studied. Damage was comparatively more to wheat at 4.4 tc14.9% compared to 5.0 to 8.2% to paddy and 1.9 to 5.0 to maize. The rodent infesting paddy were *B.bengalensis, M.musculus, M.booduga, R.metlada* and *I.rattus* of which *R.rattus* was least significant. Wheat was infested by *B.bengalesis, M.musculus, M.booduga, R.rattus* and *R.meltada*. Here the density of *R.rattus* vas more than that in rice. Maize had a slightly different pattern of infestation. *Mmusculus, B.bengalensis, M.booduga, R.meltada* and *R.rattus* were the species ound in maize fields. *R.rattus* was found in significant numbers.

(b) Fruits (Table 3) Apple : Rodent damage rnged 21.3 to 44.8%. A total of seven rodents damaged apple but only four wre major namely, *B.bengalensis* > *M.musculus* > *M.booduga* > *R.rattus*. The ensity of *R.meltada* and *M.platythrix* was insignificant. *G.ellioti* was a minor pes.

Peach : Rodent damage was not significant(1.6 to 6.7%). *M. musculus* was the predominant species followed by *B.bengalnsis, M.booduga, R.rattus* = *G.ellioti. M.platythrix* and *R.meltada* were insignificnt.

Plum : Rodent damage was negligible at 12 to 2.3%. The major species found were *B.bengalensis, M.musculus, M.boodua, G.ellioti* and *R.rattus*. To a small extent *R.meltada* and *M.platythrix* occurrec

Table 3 : Rodent damage and species inflicting damage to cultivated crops in mid hill zone of Himachal Pradesh

Crop	Cropping season, rodent damage (% range) and species involved								
	% Dam range	Species (%)							
		Bb	Rm	Rr	Ge	Mm	Mb	Mp	Fp
Cereals									
Paddy (*kharif*)	5.0-8.2	31.63(4)	18.55(4)	5.89	0	24.83(4)	19.10(4)	0	0
Wheat (*rabi*)	4.4-14.9	37.60(4)	11.44(4)	15.55(4)	0	18.49(4)	16.92(4)	0	0
Maize (*kharif*)	1.9-5.0	25.58(4)	18.08(4)	6.88	0	27.65(4)	21.81(4)	0	0
Orchard fruits									
Apple	21.3-4.8	30.42	1.5	14.84	9.8	24.94	15.03	1.38	0
Peach	1.6-6.7	23.56	1.5	13.22	13.15	30.7	15.75	2.62	0
Plum	1.2-2.3	26.05	0	10.42	8.32	27.08	22.92	-	0
Pecan	1.6-6.7	25.53	5.86	10.76	15.04	22.46	17.45	2.82	0
Tomato (Mar-July)	1.6-7.0	24.13	15.10	9.33	1.22	32.36	15.5	2.05	0
Capsicum (Mar-July)	NA	14.3	0	42.9	0	28.6	14.3	0	0
Cabbage (Oct- Mar)	2.5-90.0	3.53	8.74	18.83	7.08	36.39	22.01	3.42	0
Cauliflower curd (Oct-Mar)	2.3-8.5	23.36	15.83	7.33	2.67	28.88	17.27	4.66	0
Cauliflower seed (Oct- May/June)	3.9-12.7	26.13	14.12	10.1	0	28.12	21.6	0	0
Peas (Dec – Apr)	2.3-8.0	28.33	13.62	11.5	5.95	28.55	16.85	3.13	0

Bb = Bandicota bengalensis, Rm = Rattus meltada, Rr = Rattus rattus, Ge = Golunda ellioti, Mm = Mus musculus, Mb = Mus booduga, Mp = Mus platythrix, Fp = Funambulus pennanti. NA-Not available.

Pecan : The rodent damage was meager i.e. 1.6 to 6.7% and is mostly caused by *B.bengalensis, M.musculus, M.booduga, G.ellioti* and *R.rattus. R.meltada* and *M.platythrix* occur in negligible numbers.

Kiwi : The species composition was *R.rattus > M.musculus > B.bengalensis = M.booduga > G.ellioti.*

(c) Vegetables (Table 3) : Tomato was damaged to the extent of 1.6 to 7%. Major species inflicting damage were *M.musculus, B.bengalensis, M.booduga, R.meltada,* and *R.rattus*. Negligible occurrence of *G.ellioti* and *M.platythrix* was seen.

Capsicum : Four species infested capsicum fields namely *R.rattus, M.musculus, M.booduga* and *B.bengalensis.*

Cabbage : The crop was severely damaged by rodents ranging between 2.5-90%. The species causing damage were *M.musculus, M.booduga, R.rattus, R.meltada* and *G.ellioti*. To a very small extent *B.bengalensis* and *M.platythrix* also infested the cabbage fields.

Cauliflower : (i) Curd crop was significantly amaged at 2.3 to 8.5%. The major species infesting were *M.musculus, B.benglensis, M.booduga* and *R.meltada*. To a lesser extent *R.rattus, M.platythrix* and *G.ellioti* also affected the crop. (ii) Seed crop was damaged to the extent of 3.9 to 12.7%. Five species inflicted damage namely, *M.musculus, B.bengalensis, M.booduga, R.meltada* and *R.rattus*.

Peas : Rodent damage was 2.3 to 8.0%. Thespecies damaging the pea crop were *M.musculus, B.bengalensis, M.booduga, R.meltada and R.rattus*. To a small extent *G.ellioti* and *M.platythrix* were also seen.

DISTRIBUTION OF RODENT SPECIES IN DIFFERENT CROPS

Rodent species found in different cropecosystem of Himachal Pradesh are described as under:

1. The Indian mole rat, *Bandicota bengalensi*. : 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. However, its population is low in Kinnaur area (dry temperate zone). It inflicted damage to cereal, vegetables and fruit crops from sowing/seedling/nursery stageonwards till maturity. It also inhabited tea plantations, forests and waste/grass lands and damaged pecan nut (Sheikher and Jain, 1997). *B.bengalensis, R.meltada* and *M.booduga* caused 4.44 to 11.37% damage in curd crop and 6.51 to 13.94%in seed crop of cauliflower thereby resulting in loss up to 1755kg curd/ha and p to 53.67 kg seed/ha, respectively (Sheikher and Jain, 1997). Tea plantations hve also been reported to be infested with *B.bengalensis, M.booduga, M.musculus* and *G.ellioti* whose activity adversely affected the quality and quantity of produce Sheikher, 1999). On the basis of ten years studies, this species was found to be dominant in all the fruit, vegetable (except cabbage) and cereal crops (Table 3).

2. The soft-furred field rat, *Rattus meltada* This species is distributed chiefly in humid sub-temperate, humid sub-tropical and sub-humid sub-tropical zones of the state. It was a pest on cereal (wheat, paddy, maize) and vegetable crops and was also present in apple, peach and pecan nut orchards but in low numbers (Table 3). In citrus orchards both *R.meltada* and *B.bengalensis* dug elaborate burrows, damaged root and bark of the tree resulting in reduction in the growth and reduced fruit set (Sheikher, 1999).

3. The house rat, *Rattus rattus* : The speciesis primarily a commensal species and inhabits residential premises and stores. It ispresent in all the agro climatic zones of the state. It was also a frequent visitor to fields and was a pest foraging on all types of crops grown near human habitat On Kiwi it was the most dominant species comprising 41.5% of the total rodent population (Table 3). It has been recorded from the burrows deserted by other rat species in cauliflower fields in

the mid hills of the Solan and was also found occupying deserted bird nests atop trees (Sheikher and Sood, 2001).

4. The bush rat, *Golunda ellioti* : It has been recorded from sub-temperate, humid sub-tropical and sub-humid sub-tropical zones up to an elevation of 1200, above MSL and was present in orchards and in uncultivated areas (waste land, forests etc.) supporting bushy and grassy ground cover (Sheikher and Jain 1995). However, it has not been found in cereal crops while in vegetable crops it was recorded as a sporadic visitor. (Table 3).

5. The house mouse, *Mus musculus* : This is a commensal species which is a serious pest in the orchards, nurseries, vegetables and cereal crop fields, sugarcane fields, grasslands and wastelands. It was also present in the tea plantation, granaries, stores and residential premises. A ten year study on its population on apple, peach, plum, pecan and in curd cauliflower, seed cauliflower, cabbage, pea and tomato, revealed it be a significant pest on these crops (Table 3).

6. The Indian field mouse, *Mus booduga* : It is a common pest in all nurseries, orchards, crop field, tea plantations and grasslands up to an elevation of 2000m above MSL. In apple, peach, plum, pecan and Kiwi, and in paddy, wheat and maize, the population of this species was significant (Table 3). It was one of the major rodent species in cauliflower (Sheikher and Jain, 1997).

7. The brown spiny mouse, *Mus platythrix* : It is found in sub-humid tropical and humid tropical regions. The population of this species on different fruit and vegetable crops was found to be very low in numbers (Table 3).

8. The five striped squirrel, *Funambulus pennanti* : This species has been found in sub-humid and humid sub-tropical zones as a commensal species. It was a pest of fruit trees and maize crop. It was also observed in large numbers among the mango and *Zizyphus* plantations and nested in tree holes and consumed fallen *Zyzyphus* fruits (Bhagat and Kashyap, 1992).

9. Porcupine, *Hystrix indica* : 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 inflicted heavy damage to a variety of crops especially in the fields located near their natural habitat. Its attack was sporadic but extensive. Damage was inflicted to tuber crops, cabbage etc. and also to the young pine plantations apart from other trees in natural forests as well as in afforested areas. In Shimla district, the porcupine damage to carrot, radish and potato was found in different localities in the fields adjoining the forest strips, whereas in Sirmour and Solan districts, turmeric and ginger rhizomes have been found to be dug out. The damage to the young pine plants (*Pinus roxburghii*) was reported to be upto 90% (Sheikher, 1998). In Kangra district, damage to mango and citrus orchards was in the form of girdling and debarking

Table 4 : Major pests and diseases of crops of Himachal Pradesh

Crops	Insect/nematode pests	Disease	Rodent pests
Vegetable crops			
Cole crops	Aphids, caterpillars, red ant, painted bug.	Black rot, curdot, stalk rot, down mildew.	*Cabbage:Mm>Mb>Rr>Rm>Ge>Mp* *Cauliflower: Mm=Bb>Mb>Rm>Rr >Mp*
Peas	Pea leaf miner, pod borers, thrips.	Powdery mildew, aschochyta blight, bacterial blightwilt.	*Bb=Mm>Mb>Rm>Rr>Ge>Mp*
Tomato	Cutworm, whitefly, tomato leaf miner, pea pod borer, fruit fly, root knot nematode.	Damping of buk eye rot, bacterial wi, bacterial cankr alternaria diseses.	*Mm>Bb>Mb=Rm>Rr>Mp>Ge*
Capsicum	Termite, aphid, mite, whitefly.	Damping off frt rot, blight, anthracose mosaic.	*Rr>Mm>Bb=Mb*
Fruits crops			
Apple	Sanjose scale, woolly apple aphid, thrips, defoliating and fruit eating beetle, defoliating caterpillars, leaf folding and fruit scrapping caterpillars, apple fruit moth, borers.	Seedling bligh hairy root, crown ga white root rot, collar ot, canker and dieback, powdery mildew, leaf spot, apple sco, sooty blotch, fit rots, virus diseases	*Bb>Mm>Rr=Mb>Ge>Rm>Mp*
Stone fruits (peach, plum, apricot, kiwi etc)	Peach leaf curling aphid, blossom thrips, fruit fly, plum scale, plum fruit, moth, borers, defoliating & fruit eating beetles, bark eating caterpillars, termites.	Bacterial grumosis, peach leaf cur brown rot& blossom light, leaf spot powdry mildew, stigmia blight, silver lef & cankers white ot rot, collar rot, whit root rot.	*Mm=Bb>Mb>Rr=Ge>Rm>Mp*
Strawberry	Cutworm, white grub, hairy caterpillar	Leaf spot, grmould.	NA*
Grapes	Defoliating beetle, thrips, jassids, leaf roller, yellow & red wasps.	Powdery mildew, downy mildew anthracnose, lack rot.	NA*
Mango	Mango, hopper, psylla, mealy bug, stem borer, shoot borer, bark eating caterpillar.	Anthracnose, owdery mildew mango malformation, ie-back, mottle lef.	NA*
Litchi	Leaf curl mite.	Red rust.	NA*
Guava	Fruit fly, stem borer.	Anthracnose, anker.	NA*
Cereals			
Paddy			*Bb>Mm>Mb>Rm>Rr*
Wheat			*Bb>Mm>Mb>Rr>Rm*
Maize			*Mm>Bb>Mb>Rm>Rr*

NA*-Not available

due to gnawing habit of the animal, particularly in the orchards located near forest, wasteland or grassland and where wheat was sown as intercrop (Sood and Sheikher, 2000).

10. The Indian gerbil, *Tatera indica* : This species has limited distribution in Himachal Pradesh, having been recorded only from the foothills of Solan district (humid sub-tropical and humid sub-temperate zones). It was also reported from wasteland and grasslands.

CONCLUSIONS

The data on rodent species composition has been well established for all the zones but exhaustive account is available for sub-tropical, sub-montane and low hills (zone 1) and sub-temperate, sub-humid mid hills (Zone 2). The species damaging major fruit, vegetable and cereal crops have been established along with the extent of damage.

V. KARNATAKA

Spread over 1.92 lakh sq. km Karnatka occupies eighth position in the country area wise. It is situated 11.5° N latitde and 74.2° and 78.4° E longitude. Agriculture contributes 63% to the state's income. Of the 19.1 million hectares, net area sown is 10.3 million ha. forming 54% of cultivated land. Of this only 20% is irrigated, 70% falls under "Dry zone"and only 10% of the net area sown has assured rainfall. Monocropping is the rle due to unpredictable and scanty rainfall. However in the assured rainfall ares of hilly, coastal and transitional zones double cropping is practiced. Soil is vried. River basins and coastal areas have alluvial soils, black soil characterisesnorthern plains while laterites and laterite soils are found in western hilly region of heavy rainfall. Climate is tropical with typical monsoon rainfall. The temperatue extremes are 12°C to 13°C during winter and 42°C during summer. Rainfall is rceived in three distinct phases viz., pre-monsoon rainfall between March and May, South-West Monsoon between June and September, North-East monsooi from October to December with absolutely no rains during January to March Drought is a recurring phenomenon in more than half the state spread across ive of the 10 agro climatic zones namely, North-eastern dry zone, North-dry one, Central dry zone, Eastern dry zone and Southern dry zone. Thus the choic of crops depends on the onset of monsoon and its distribution

CROPS AND CROPPING SYSTEM

The major food crops such as paddy, jwar, bajra (pearl millet), maize, ragi (finger millet) and tur (red gram) are grown i 74.86 lakh ha. while in 19.74 lakh ha. oil seeds, sesame, groundnut and sunlower are cultivated. Groundnut is grown more than other oil seeds. Coastal ad hilly areas grow plantation crops like areca nut, coconut, cashew, coffee, peppr, cardamom etc. Horticulture is an important and integrated component of state; agriculture. The major horticultural crops are mango, banana, citrus, sapota, grapes, and pomegranate. Of late strawberry cultivation is taken up on large cale in northern Karnataka. Potato, tomato, brinjal, French beans, cucurbits, cpsicum, chillies, different kinds of gourds, spice crops are grown widely. Flor:ulture especially around Bangalore contributes significantly to farmer's incme. Major flowers cultivated are chrysanthemum, jasmine, lilies and roses forexport.

With sericulture being an important agp-industry in the state, mulberry is cultivated in vast areas of southern districts of the state.

AGROCLIMATIC ZONES (Table 1, Fig. 1)

Based on topography, rainfall and soil ype, Karnataka has been delineated into ten Agroclimatic zones. The zones are lorth Eastern Transition zone, North Eastern Dry zone, Northern Dry zone, Central ry zone, Eastern Dry zone, Southern

Dry zone, Southern Transition zone, Northern Transition zone, Hilly zone and Coastal zone.

1. NORTH EASTERN TRANSITION ZONE : It is the smallest agricultural zone of the state and covers the entire district of Bidar, Aland and Chincholi talukas of Gulbarga district. Elevation 633-807ft. above MSL. Average rainfall is 870mm occurring between June to October the range being 633-807mm. The predominant soil types are red laterites and black soils of varying depth. The major crops cultivated are jowar, black gram, green gram, red gram, Bengal gram, groundnut, sunflower, sesame and cotton.

2. NORTH EASTERN DRY ZONE : This zone comprises of Deoburg, Manvi and Raichur talukas of Raichur district and all the talukas of Gulbarga excepting Aland and Chincholi. Elevation is 800-900 ft. above MSL The average rainfall is 710mm (830-919mm range). Temperature range is 28 to 44°C in summer and 16 to 31°C in winters. Soil is predominantly medium to deep black. A small area has light red soils. The area is predominantly rabi farming area. Major crops grown are jowar, oil seeds, bajra, maize, groundnut, red gram, cotton, sun flower, pulses and cotton.

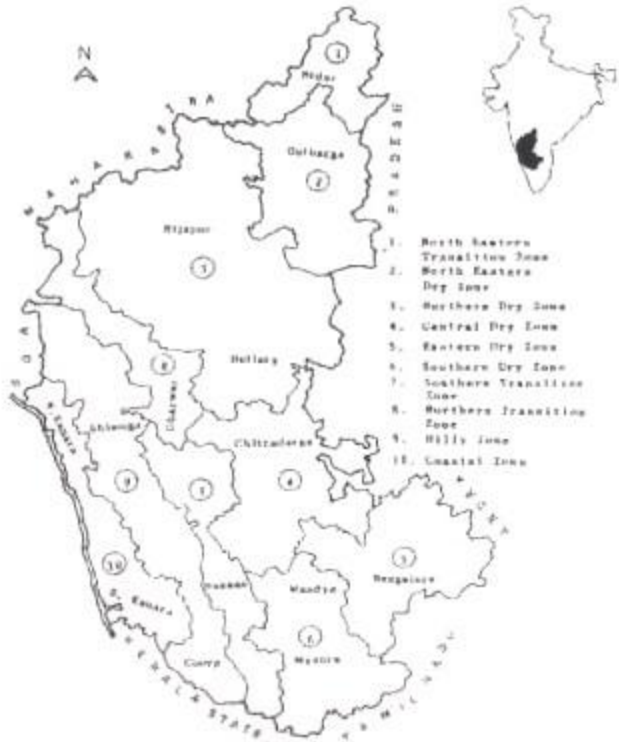


Fig. 1. Agroclimatic zones of Karnataka

Table 1 : Details of district/taluk, rainfall, soil type, cropping system, major crops and rodent pests in different agro-climatic zones of Karnataka

Zones	Districts/taluks	Soil types	Rainfall (mm)	Major crops	Major rodent pest species
NORTH EASTERN TRANSITION ZONE (*Kharif* cropping)	Entire Bidar district, Aland & Chincholi taluks of Gulbarga.	Shallow, Medium black Part of the zone is red and lateritic.	870mm June – Oct	JOWAR, BLACK GRAM, GREEN GRAM, RED GRAM, GROUNDNUT, COTTON, BENGAL GRAM	*Bb=Mm>Ti>Mus sp.*
NORTH-EASTERN DRY ZONE (*Rabi* farming)	Devdurg, Manvi & Raichur tlks of Raichur Dt. & entire Bidar Dt. except the tlks of Aland and Chincholli.	Medium to deep black. Few tlks have light red soils.	710mm June-Oct	JOWAR, BAJRA, RED GRAM, G.NUT, SESAMUM, COTTON, SAFFLOWER.	*Bb=Mm>Ti>Mb>Mp*
NORTHERN DRY ZONE (*Rabi* cropping)	Large zone covering 35 taluks in Bijapur, Bagalkot, Bellary, Raichur, Koppal, Belgaum, Gadag, Dharwad and Davanagere Dts.	Black & Red soil. More of Black	574mm Bimodal July-Sept.	JOWAR, BAJRA, MAIZE, RED GRAM, G.NUT, HORSE GRAM, SETARIA, SESAME.	*Bb>Ti>Mb>Mm>Mp*
CENTRAL DRY ZONE (*Kharif* cropping)	Entire Chitradurga, parts of Davanagere, Hassan, Chikamagalore and Tumkur Dts.	Red loamy, Medium deep soils in northern districts.	454-718mm Sept-Oct	JOWAR, RAGI, GROUNDNUT, COTTON, BAJRA	*Bb>Ti>Mm>Mb*
EASTERN DRY ZONE (*Kharif* cropping)	Parts of Tumkur Dt. and entire Kolar & Bangalore Dts.	Red loamy, laterite, low in retentive quality.	679-889mm Two peaks May, Sept-Oct	RAGI, GROUNDNUT, HORSE GRAM, RICE, JOWAR, MAIZE, MULBERRY, COW PEA, RED GRAM, VEGETABLES.	*Bb>Ti=Mm>Mb=Mp*

Zones	Districts/taluks	Soil types	Rainfall (mm)	Major crops	Major rodent pest species
SOUTHERN DRY ZONE (*Kharif* cropping of canal irrigation)	Parts of Mysore, Tumkur and Mandya Dts, small parts of Hassan Dt.	Red sandy loamy. Pockets of black soil.	670-889mm. Two peaks May Sept-Oct	JOWAR, RAGI, PULSES, COWPEA, GREEN GRAM, PADDY, BLACK GRAM, HORSE GRAM, SUGARCANE, MAIZE.	*Mm>Bb>Mb>Ti*
SOUTHERN TRANSITION ZONE	Parts of Hassan, Chickamagalore, Shimoga and Mysore Dts.	Red loamy. Red sandy loamy.	611-1054mm May-Nov	RAGI, JOWAR, PADDY, POTATO, PLANTATION CROPS.	*Bb>Mb>Mm*
NORTHERN TRANSITION ZONE (Both *Kharif* and *rabi* cropping)	Narrow strip stretching from Chikodi tlks in Belgaum Dt. to Hirekerur tlk in Haveri Dt.	Shallow to Med. Black clay, Red sandy loam.	619-1303 June-Oct	JOWAR, BAJRA, GROUNDNUT, COTTON, COWPEA, GREEN GRAM, BENGAL GRAM, RED GRAM.	*Bb>Mm>Ti>Mus sp*
HILLY ZONE (*Kharif*, plantation crops)	Parts of Uttara Kannada, Belgaum, Shimoga, Chickamagalore, Dharwad & Kodagu Dts.	Red clay Loamy. To some extent laterite.	905-3695 June-Oct	PADDY, COCONUT, BLACK GRAM, ARECA, CARDAMOM, COFFEE.	*Bb>Fpm>Bi>Mm*
COASTAL ZONE (*Kharif* plantation crops0	Parts of Uttara Kannada, Dakshina Kannada and Udupi Dts.	Red laterite, Coastal alluvial.	3011-4695mm May-Nov	PADDY, COCONUT, CASHEW, ARECA NUT, COCOA.	*Rm>Rrw>Fpm>Ft>Bi>Vo*

3. NORTHERN DRY ZONE : It is the largest agricultural zone of the state covering 35 taluks in Bijapur, Bagalkot, Bellary, Raichur, Koppal, Belgaum, Gadag, Dharwad and Davanagere districts. The zone is characterised by high percentage of irrigation. Rainfall received is 585mm, the lowest in the state. The total rainfall is not only scanty but highly erratic and intense resulting in huge run off and soil loss. Droughts are common and cyclical, occurring every 4th or 5th year. Maximum temperature is 29.6°C to 38°5 in summer and minimum is 22°C to 23°C. Black and red soils are predominant. The zone is a predominantly rabi farming area. The major crops are sorghum, bajra, groundnut, cotton, wheat, oil seeds including sunflower, sesame, safflower, linseed and pulses comprising red gram, horse gram, black gram, green gram and Bengal gram.

4. CENTRAL DRY ZONE : This zone consits of entire Chitradurga, parts of Davanagere, Hassan (Arasikere), Chickmaalore (Kadur taluka), Madhugiri, Pavagada, Sira, Koratgere and Chikkanayakaahalli talukas of Tumkur districts. Elevation is 456-800ft. above MSL. The soils are red loamy and medium deep soils. The rainfall range is 454-718mm receied during September-October. The major crops cultivated are ragi, pulses, (cow pea, black gram, horse gram and Bengal gram), sorghum, groundnut, rice, cotto, bajra, minor millets, paddy, maize and plantation crops.

5. EASTERN DRY ZONE : The region comprises the entire districts of Kolar, Bangalore, Gubbi and Tumkur talukas of Tumur district. The soils are red loamy and lateritic, low in retentive quality. The eleation is 800-1500 ft. above MSL. The range of rainfall is 679-889mm received i two peaks in May and September-October. Ragi, jowar, maize, fodder, paddy, groundnut, soybean, potato, mulberry and pulses such as horse gram, Bengal gram, green gram, red gram are the major crops.

6. SOUTHERN DRY ZONE : It comprises of K.R.Nagar, T.N.Pura, Mysore, Kollegal, Nanjangud, Chamarajanagar, Gundlupet, Yelndur, talukas of Mysores district, Turuvekere and Kunigal talukas of Tumkur district, Nagamangala, Srirangapatna, Malavalli, Maddur, Mandya, Pandavapura, K.R.Pet of Mandya district and Channarayapatna of Hassan district. The elevation of the zone ranges 450-900 ft. above MSL. Soil is red sandy loam and a fewpockets of black soil. Rainfall range is 670-889mm. Major crops are ragi, sorgum, paddy, groundnut, oil seeds, mulberry, plantation crops, sugarcane, maizeand pulses (cow pea, green gram, black gram and horse gram).

7. SOUTHERN TRANSITION ZONE : This zonecomprises Holenarasipur, Alur, Belur and Arkalgud talukas of Hassan district, Bhadravathi, Shimoga, Shikaripur, Honnali and Channagiri talukas of Shimoga and H.D.ote, Hunsur, Periapatna talukas of Mysore district. Elevation is 450-900ft. aboveMSL. The soils are red loamy, and red sandy loam. The range of rainfall is 611-054mm. The major crops are ragi, groundnut, rice, sorghum, sugar cane, maize groundnut, cotton, fodder, pulses such as cowpea, horse gram, Bengal gram ard plantation crops.

8. NORTHERN TRANSITION ZONE : It compises Hukkeri, Chikkodi, Bailhongal, Belgaum talukas of Belgaum district, Haveri, Shggaon, Shirahatti, Kundgol, Savanur, Hubli, Dharwad, Byadagi, Hirekerur and Raibennur talukas of Dharwad and Ranibennur districts. The range of rainfall is 69-1303mm. Elevation is 800-900ft. above MSL. in most of the area and a fewareas lie at 450-800 ft. Soils are shallow to medium black clay and red sand loam. Important crops are jowar, pulses, groundnut, paddy, ragi, fodder, smal millets, sugarcane, cotton, wheat and horticultural crops.

9. HILLY ZONE : The hilly zone is constitutd by Sakleshpur taluka of Hassan district, Virajpet, Somwarpet, Mercara talukas of Coorg districts, Kalghatgi, Hangal

talukas of Dharwad district, Koppa, Sringeri, Mudigere, Nasasimharajapura of Chickmagalore district, Sirsi, Siddapur, Yellapur, Sapa, Haliyal, Mundgod talukas of North Canara district and some talukas of Shimoga district. Major area lies at an elevation of 400-900 ft. above MSL. and a few taluks at 900-1500ft. above MSL. Rainfall range is 904-3695mm. Soils are red clay and loamy. Principle crops are jowar, gram, pulses, paddy, maize, ragi, sugarcane, cotton, spices and plantation crops.

10. COASTAL ZONE : It comprises Karwar, Kumta, Honnavara, Bhatkal, Ankola talukas of North Canara district and Udupi, Kundapur, Mangalore, Bhantwal, Karkala, Belthangadi, Puttur, Sulya talukas of South Canara and Udupi districts. This is the zone of highest rainfall in the state which ranges 3011-4694mm. Most of the area lies at less than 300 ft. above MSL and a small area at 450-800ft. Soils are red lateritic and coastal alluvial. Pulses, groundnut, paddy, tubers, sugarcane and plantation crops predominate.

DISTRIBUTION OF RODENT SPECIES (Table 2)

There is great diversity of rodent species infesting crop fields of Karnataka. These species are *B.indica, B.bengalensis, R.rattus, R.meltada, R.r.rufescens, R.r.wroughtoni, F.palmarum, F.tristriatus, H.indica, M.platythrix, M.booduga, M.musculus, T.indica and V.oleracea*. The species complex in the crop fields of Southern plains consists of *B.bengalensis, B.indica, R.meltada, T.indica*, and *Mus* species. In hilly regions *H.indica* and *F.tristriatus* become major pests and coastal areas are heavily infested by *F.tristriatus, R.r.rufescens* and *R.r.wroughtoni*. Surveys in different zones indicated that in Northern Transition Zone *R.meltada* was the predominant species during summer while *B.bengalensis* was more numerous during rainy season. The third abundant species was *T.indica*. In northern dry zone *B.bengalensis* and *M.meltada* were the major species followed by *Mus* species and *T.indica*. In Central dry zone *M.meltada, T.indica* and *B.bengalensis* were the predominant species (Table 2).

PESTS STATUS OF RODENTS AND CROPWISE DAMAGE (Table 2; Plate 5) (Fig. 2 &3)

(a) Rice: *B.bengalensis* occurred extensively at all stages of paddy growth namely, germinating, vegetative growth, pre harvest and post harvest stages in the five zones studied viz., Eastern dry, Southern Dry, Central Dry, Southern Transition and Northern Zones. The next two abundant species were *M.meltada* and *M.booduga*. *T.indica* was seen only during germination, vegetative growth and post harvest stages. Damage was 6-10% at grain maturation stage.

(b) Ragi: There was a clear dominance of *B.bengalensis, T.indica* and *M.meltada* at all the four stages of ragi growth. The two *Mus* species were found less frequently. The data was from Eastern dry and Central dry zones. Ragi was damaged to the extent of 6-12% at grain maturation stage.

Table 2 : Rodent species infesting major food crops of Karnataka

	NETZ	NEDZ	NDZ	CDZ	EDZ	SDZ	STZ	NTZ	HZ	CZ
Paddy			*Bb>M >Mm*	*Bb*	*Bb>M >Mr*	*Mm>B b>Mb*	*Bb>Mb >Mm*	-	*Bb> Mm*	*Bb*
Ragi				*Bb>Ti> Mm> Mus*	*Bb>M> Ti> Ms*					
Maize				*Bb>M m*	*Bb>T· Mm>Ms*			*Bb=M m>Mp*		
Jowar					*Bb>M> Mb>*			*Bb>M m>Ti> Mb*		
Wheat		*Bb>M m>M us sp.*	*Bb>Ti >Mp*					*Bb*		
Red gram	*Bb>Mm >Mb*				*Bb>T· Mm>Ms*			*Bb>M m>Mu s>Ti*		
Ground nut				*Bb>M m>Ti> Mb*	*Bb>M> Ti=Ms*		*Bb*			
Soybean					*Bb>T· Mm>Ms*			*Bb>M m*		
Sunflower								*Bb=M m> Mus>T i*		
Sugarcane	*Bb>Mm >Mb*									

NETZ-North Eastern Transition Zone; NEDZ-North Easter Dry Zone; NDZ-Northern Dry Zone; CDZ-Central Dry Zone; EDZ-Eastern Dry Zone; SDZ-Southern Dry Zone; STZ-South Transition Zone; NTZ-North Transition Zone, HZ-Hilly Zone; CZ- Coastal Zone

(c) Maize: The rodent pests were slightly diffrent in maize fields of Eastern Dry, Central Dry and Northern Transition Zones The usual triplet of rodents i.e. *B.bengalensis, M.meltada* and *T.indica* were predominant at all the four stages of maize growth in Eastern Dry zone. In central Dry zone only *B.bengalensis* and *M.meltada* were seen. In Northern Transition Zone both *B.bengalensis* and *M.meltada* were major species followed by *Millatythrix*. At pre harvest stage only bandicoots and metads were seen. Damage was 4% at seedling and 12.5% at preharvest stage.

(d) Jowar: Rodent infestation was seen only during sowing stages when 4-7% of sown seeds were consumed by rodent pests. The species involved were *B.bengalensis, M.meltada, M.booduga* and *T.indica*. At the other stages of growth no rodent infestation was seen in jowar in Eastern Dry Zone. In Northern Transition Zone *B.bengalensis* and *T.indica* were seen at vegetative growth and *B.bengalensis, M.meltada* and *M.booduga* were observed at preharvest stage.

Table 3. Rodent species composition and damage in food and vegetable crops of Karnataka (Sridhara, 1999; Chakravarthy *et al.*, 1998)

Crop	Zone/ Year(s)	Presowing/germinating			Vegetative growth			Preharvest (grain maturation)			Post harvest	
		Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]	Da[2]	Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]
FOOD & OIL CROPS												
PADDY (*Oryza sativa*)	Eastern Dry zone (1980-2004)	*Bb>Mb> Mm*	8	-	*Bb>Mm> Mb>Fpm> Sm>Ti*	14	3	*Bb>Mm> Mb>Sm> Mp*	27	6	*Bb>Mb>Ti*	30
	Southern Dry (1982-83)	*Ti>Bb*	5	-	*Mm>Bb> Mb*	25	4	*Mm>Bb> Mb*	38	10	*Bb>Mm> Mb*	20
	Central Dry	-	-	-	*Bb*	10	3	-	-	-	-	-
	Southern Transition (1991-92)	-	-	-	*Bb>Mb> Mm*	13	-	-	-	-	-	- -
	Northern Dry (1997-2002)	-	-	-	*Bb>Mb> Mm*	19	2.5	*Bb>Mb*	30	3	-	- -
	Coastal zone	*NA*	-	-	*NA*	-	-	*Bb*	-	-	*NA*	-
RAGI (*Eleusine coracana*)	Eastern Dry (1986-2004)	*Bb>Mm>Mp >Ti>Mb*	8	-	*Bb>Mm=Ti >Mb>Mp*	14	3	*Bb>Mm> Ti>Mb>Mp*	19	12	*Bb>Mm>Ti >Mp>Mb*	11
	Central Dry (1988-89)	-			*Bb>Ti> Mm>Mb*	23	-	*Bb>Ti>Mp*	-	6	*Bb>Mm>Ti*	-
MAIZE (*Zea mays*)	Eastern Dry	*Bb>Ti>Mb> Mm>Mp*	22	40-80	*Bb>Ti>Mm >Mp>Mb*	18	2	*Bb>Ti> Mm>Mb> Mp*	11	0.3	*Bb>Ti>Mm >Mb>Mp*	8
	Central dry (1988-89)	-	-	-	*Bb>Mm*	15	-	-	-	-	-	-
	Northern Transition (1999-2001)	*Mm>Mp>Bb*	5	4	-	-	-	*Bb>Mm*	8	12.5	-	-
JOWAR (*Sorghum vulgare*)	Eastern Dry (2001-02)	*Bb>Mm>Mb >Ti*	16	4-7	-	-	-	-	-	-	-	-
	Northern Transition (1997-02)	-	-	-	*Bb>Ti*	12	-	*Bb>Mm> Mb*	10	-	-	-

Crop	Zone/ Year(s)	Presowing/germinating			Vegetative growth			Preharvest (grain maturation)			Post harvest	
		Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]	Da[2]	Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]
WHEAT (*Triticum aestivum*)	Northern Dry (1995-96)	-	-	-	-	-	-	*Bb>Ti>Mp*	18	6	-	-
	Northern Transition (1996-97)	-	-		-	-	-	*Bb*	12	10	-	-
	Northern East Dry (1996-2002)	-	-	-	*Bb>Mm> Mb*	10	1.5	*Bb>Mm> Mp*	14	5	-	-
RED GRAM (*Cajanus cajan*)	Eastern Dry (1988-2004)	*Bb=Ti>Mm> Mb>Mp*	12	50-100	*Bb=Ti>Mm >Mb>Mp*	11	1	*Bb>Mb> Mm>Mp> Ti*	20	2	*Bb>Ti=Mp> Mm>Mb*	7
	Northern Transition (1999-2002)	-	-	-	*Bb>Mm> Mp>Ti*	6	-	*Mm>Bb> Mb>Mp*	10	-	-	-
	North Eastern Transition (2002-03)		-		*Bb>Mm> Mb*	6	-	-		-	-	-
GROUND NUT (*Arachis hypogea*)	Eastern Dry (1988-2004)	*Bb>Mb>Mm >Ti>Mp*	20	30-40	*Bb>Mm>Ti >Mb>Mp*	19	4	*Bb>Mm> Ti>Mp>Mb*	27	7	*Bb>Mm> Mp>Ti>Mb*	20
	Central Dry (1988-89)	-	-	-	*Bb>Mm>Ti >Mb*	13	6	-	-	-	-	-
	Southern Transition (1991-92)	-	-	-	*Bb*	9	-	*Bb*	16	4	-	-
	Northern Transition (2000-01)	-	-	-	-	-	-	*Bb>Mm*	19	12	-	-
SOYBEAN (*Glycine max*)	Eastern Dry (1996-2004)	*Bb>Mb>Mm =Ti>Mp*	28	-	*Bb>Ti> Mm>Mp*	8	-	*Bb>Mm> Ti>Mb>Mp*	25	3	*Bb>Ti>Mm >Mp>Mb*	30
	Northern Transition (2000-2001)	-	-	-	*Bb>Mm*	8	3	-	-	-	-	-

Crop	Zone/ Year(s)	Presowing/germinating			Vegetative growth			Preharvest (grain maturation)			Post harvest	
		Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]	Da[2]	Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]
SUNFLOWER (*Helianthus anus*)	Eastern Dry (1990-2001)	*Bb>Mm>Mp >Ti*	16	70	*Bb>Ti>Mm =Mp>Mb*	7	1	*Bb>Mp> Mm>Ti*	6	-	*Bb>Mm= Mp*	5
	Central Dry (1988-89)	-	-	-	*Ti>Bb*	13	-	-	-	-	-	-
SAFFLOWER (*Carthamus tinctorius*)	Northern Transition (1999-2002)	*Mm>Bb>Mp*	16	6	*Bb>Mm> Mb=Mp>Ti*	13	1	-	-	-	-	-
COMMERCIAL CROPS												
COTTON (*Gossypium spp.*)	Southern Transition (1991-92)	-	-	-	*Bb=Ti=Mm*	14	-	-	-	-	-	-
	North Eastern Transition (2002-03)	-	-	-	*Mm*	8	-	-	-	-	-	-
	Northern Transition (1998-2002)	-	-	-	*Mm>Bb=Ti >Mp*	8	-	*Mm>Bb> Ti>Mb>Mp*	24	3	*Mm>Bb*	34
	Northern Dry (1996-97)	-	-	-	-	-	-	*Bb>Mm> Ti>Mp*	16	-	-	-
SUGARCANE (*Saccharum officinarum*)	North Eastern Transition (2001-02)	-	-	-	*Bb>Mm> Mb*	12	6	-	-	-	-	-
MULBERY (*Morus spp.*)	Eastern Dry (1987-2004)	-	-	-	*Bb>Ti>Mm >Mp*	12	-	*Bb>Ti> Mm>Mb*	15	2	-	-
MARIGOLD (*Tagetes erecta*)	Eastern Dry (2001-02)	-	-	-	-	-	-	Fpm>Bb> Ti>Mp	15	3	*Bb*	6
COFFEE (*Coffea arabica*)	Hilly zone (1990-91)	-	-	-	*Mm>Mp*	3	-	Fpm	-	-	-	-
ARECANUT (*Areca catachu*)	Eastern Dry (1991-2003)	-	-	-	*Bb>Mm> Mb*	21	-	Bb>Mb>Ti >Fpm	14	-	-	-

Crop	Zone/ Year(s)	Presowing/germinating			Vegetative growth			Preharvest (grain maturation)			Post harvest	
		Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]	Da[2]	Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]
COCONUT (*Cocos nucifera*)	Eastern Dry (1987-1999)	-	-	-	-	-	-	*Rr>Bb>Mm>Ti>Mp*	15	6.8-80	-	-
	Coastal zone		-	-	-	-	-	*Rrr, Rr*	-	-	-	-
OIL PALM (*Elaeis guineensis*)	Northern Dry (1999-2001)	-	-	-	*Bb>Ti>Mp*	23	4	*Bb>Mm>Ti*	20	10	-	-
III FRUIT CROPS												
GUAVA (*Psidium guajava*)	Eastern Dry (1987-2003)	-	-	-	-	-	-	*Bb>Mm=Ti>Mb*	34	3	-	-
SAPOTA (*Acrus sapota*)	Eastern Dry (1995-2001)	-	-	-	*Ti=Bb>Mp>Mm>Mb*	15	0.5	*Fpm>Bb>Ti=Mp>Mm>Mb*	18	10	*Bb>Mm>Ti>Mp>Mb*	17
POMEGRANATE (*Punica granatum*)	Eastern Dry (1997-1999)	-	-	-	*(Flowering stage) Bb>Mm>Mus*	14	-	*Fpm>Bb>Mm>Mp=Mb*	15	12	-	-
(*Vitis vinifera*)	(1986-2004)							*Ti>Mp*				
BANANA (*Musca sapientun*)	Eastern Dry (2002-2004)	-	-	-	-	-	-	*Bb>Mb=Ti>Mp*	19	1	-	-
IV. VEGETABLE CROPS												
CUCUMBER (*Cucumis sativus*)	Eastern Dry	-	-	-	-	-	-	*Bb*	18	10	-	-
BEETROOT (*Beta vulgaris*)	Eastern Dry (2002-2004)	-	-	-	*Bb>Mp>Ti*	15	5	*Bb>Ti>Mp*	13	4	-	-
BRINJAL (*Solanum melongena*)	Eastern Dry (2001-2004)	-	-	-	*Bb>Mm>Mb>Ti*	19	3	*Bb>Mm>Mp*	18	6	-	-
CABBAGE (*Brassicia oleracea var capitata*)	Eastern Dry (2004-05)	-	-	-	*Bb>Mp>Mb*	12	5.5	*Bb>Ti*	10	5.5	-	-

Crop	Zone/ Year(s)	Presowing/germinating			Vegetative growth			Preharvest (grain maturation)			Post harvest	
		Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]	Da[2]	Sp. comp	De[1]	Da[2]	Sp. comp.	De[1]
CARROT (*Daucus carota*)	Eastern Dry (2004-05)	-	-	-	*Bb>Mp*	18	4	*Bb*	25	5	-	-
CAULI FLOWER (*Brassica oleracia*)	Eastern Dry (2001-2003)	-	-	-	-	-	-	*Bb>Mm> Mb>Ti*	19	6	-	-
CHOW-CHOW (*Sechium edule*)	Eastern Dry (2001-2002)	-	-	-	-	-	-	*Bb>Mm> Mp*	11	-	-	-
KNOL-KHOL (*Brassica oleracea var gongylodes*)	Eastern Dry (2002-2005)	-	-	-	*Bb>Mm=Ti =Mp*	14	3	*Bb*	15	6	-	-
ONION (*Allium cepa*)	Eastern Dry (1998-2000)	-	-	-	*Bb>Mm= Mp*	11	6	*Bb>Mb> Mp*	14	-	-	-
POTATO (*Solanum tuberosum*)	Eastern Dry (2003-2004)	-	-	5	*Bb*	5	4	-	-	5	-	-
TOMATO (*Lycopersicon esculentum*)	Eastern Dry (1986-2005)	-	-	-	*Bb*	14	4	*Bb>Mp> Mm>Ti> Mb*	14	4	*Bb=Ti>Mm >Mp*	15
FRENCH BEAN (*Phaseolus vulgaris*)	Eastern Dry (2002-2003)	-	-	-	-	-	-	*Bb>Mp> Mm*	15	5	-	-
V. PLANTATION CROPS												
CARDAMOM (*Elettaria cardamomum*)	Hilly zone 1987-89	Winter *Bb>Ti>Mm> Fpm*	15	-	Summer *Bb>Fpm*	8	-	Rainy *Bb>Mm> Ti*	23	12.6		
		Also trapped were *M.booduga, Ratufa indica, B.indica* and *F. sublineatus*										
COCOA (*Theobroma cocoa*)	Coastal zone	-	-	-	-			*Ft>Rr>Vo*	-	48		
RUBBER (*Hevea brasiliensis*)	Coastal zone				*Bi* (Debarking							

Legend : 1-Density, 2-Damage (%)

(e) Wheat: There was no rodent infestation at seed germination and post harvest stages. During vegetative growth *B.bengalensis*, *M.meltada* and *M.booduga* were seen in Northern Dry Zone only. At the time of grain maturation only *B.bengalensis* infested wheat fields in Northern Transition Zone and *B.bengalensis*, *T.indica* and *M.platythrix* in Northern Dry Zone. Damage was 5-10%

(f) Red gram: Although rodents were present in red gram fields from seedling to harvest and post harvest stage, yet damage of 50-100% was seen only at seedling stage. *B.bengalensis* and *M.meltada* were the predominant species followed by *Mus* species.

(g) Groundnut: *B.bengalensis* was the most prevalent species followed by *M.meltada*. The two *Mus* species also occurred. Damage was 30-40% at seedling stage and 4-12% at pod maturation stage.

(h) Soybean: Damage was negligible (3%). *B.bengalensis, T.indica* and *M.meltada* were the major pests.

(i) Sunflower: *B.bengalensis* and *M.meltada* were predominant. Gerbils and the two *Mus* species occurred to a small extent. Damage was 70% to sown seeds and nil to mature seeds.

(j) Cotton: Damage was 3% to seeds. *M.meltada* was the most abundant species. Bandicoots and gerbils were also present.

(k) Sugarcane : The crop was damaged to the extent of 6% by *B.bengalensis, M.meltada* and *M.booduga*.

(l) Mulberry : Its roots were damaged (2%) by the burrowing activity of *B.bengalensis*. Other species present were gerbils, metads and *Mus*.

(m) Marigold: Damage was 3% due to squirrels, *F.palmarum* feeding on flowers. Burrows of bandicoots, gerbil and *Mus* were seen.

(n) Coffee and Areca nut : These crops were damaged by squirrels but the damage was not quantified.

(o) Coconut : It was damaged by *R.rattus* at crown level in interior Karnataka. In coastal areas *R.r.rufescens* and *R.rattus* damaged coconuts. *B.bengalensis* was a pest in coconut nurseries. Other species were *M.meltada* and *T.indica*.

(p) Cocoa : The pods suffered rodent damage upto 48% by *R.rattus, F.tristriatus* and *V.oleracia*

(q) Oil palm : It was damaged upto 10%. Species infesting were *B.bengalensis, M.meltada* and *T.indica*.

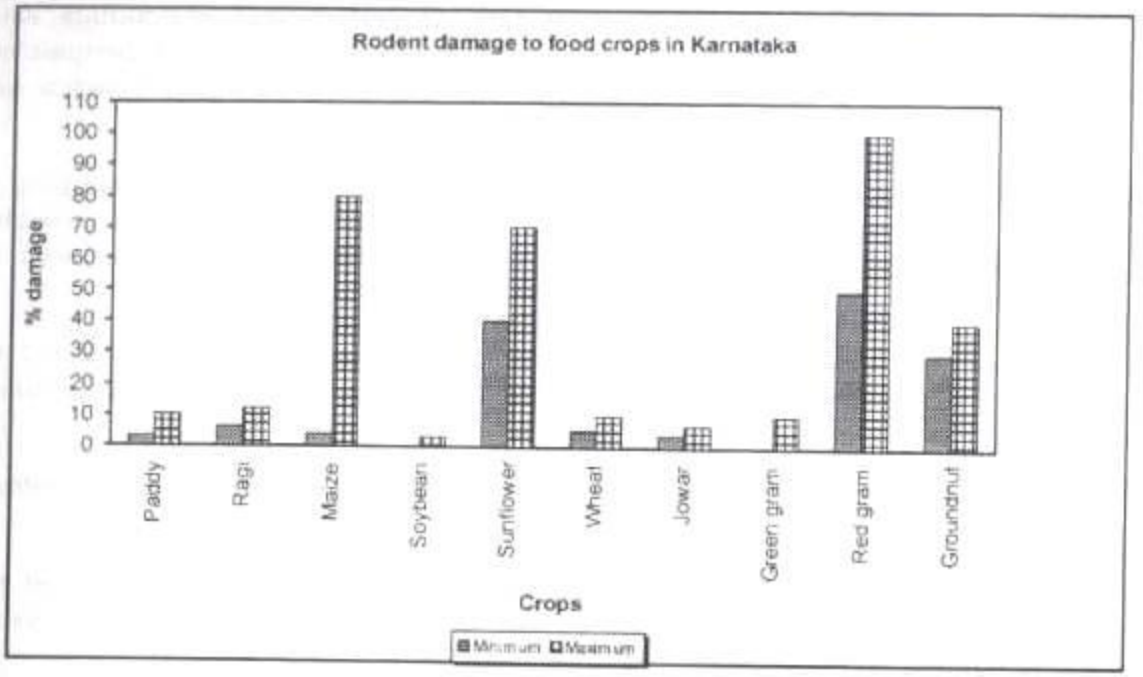


Fig. 2. Rodent damage to food crops in Karnataka

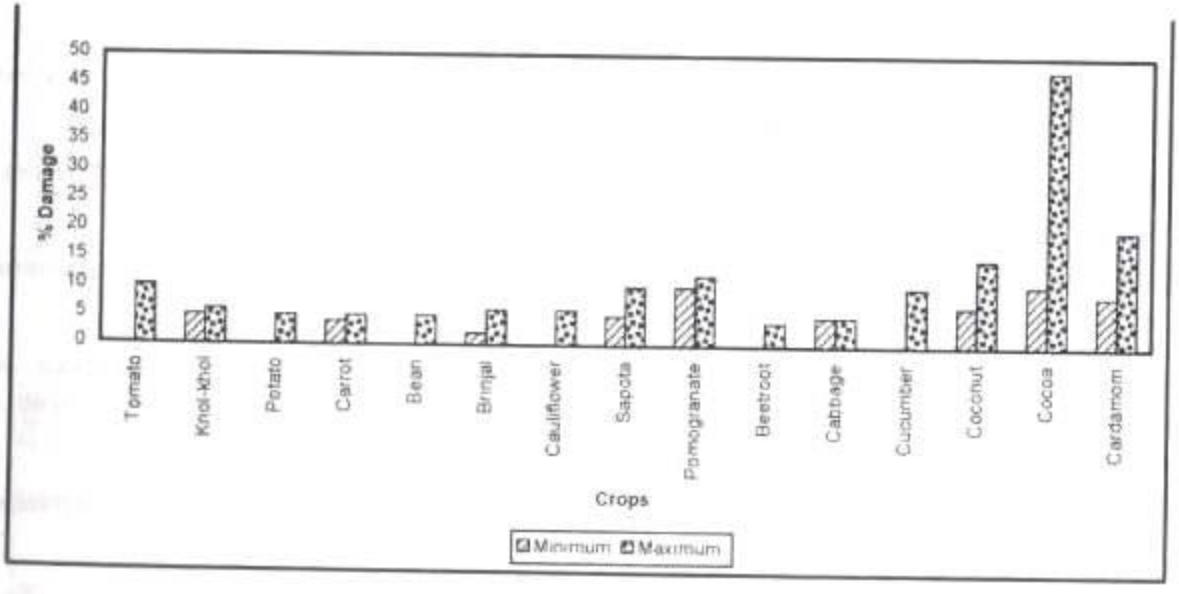


Fig. 3. Rodent damage to vegetables, fruits and plantation crops in Karnataka

(r) Fruits: Damage was 3% to guava, 10% to sapota, 12% to pomegranate, nil to grapes and 1% to banana. Although burrows of *B.bengalensis, M.meltada, T.indica* and *Mus* species were seen, yet visibly *F.palmarum* damaged sapota and pomegranate.

(s) Vegetables : The vegetables, viz., beetroot brinjal, cabbage, carrot, cauliflower, chow-chow, knol-khol, onion, potato, tomato, cucumber and French bean suffer rodent damage to the extent of 4-6%. Themajor species were *B.bengalensis*. Gerbils, metads and *Mus* also occurred to a ome extent (Fig. 2).

SEVERITY OF RODENT DAMAGE IN KARNATAKA

A comparison of extent of rodent darage to different crops reveals that almost all cultivated crops in Karnataka are susceptible to rodent attack. Seedling damage is maximum to soybean, jowar, red gram and groundnut, sometimes forcing the farmer to resow two to three times. The only crop that is not damaged above ground is soybean. Food grains such as paddy, ragi, maize and wheat are damaged 10% and above (Tables 2 & 3; Figs 1 & 2).

Almost all vegetables cultivated are damged between 4-6%. Amongst fruits pomegranate and sapota were damaged around 10% mostly by squirrels. The maximum damage was to plantation crops. Cocoa is the worst suffered followed by cardamom and coconut. In view of the high export value, the enormous damage caused by rodents to these crops is an alarming problem.

BIOLOGY AND LIFE HISTORY OF MAJOR RODENT SPECIES OF KARNATAKA

Knowledge on breeding season and periods of low or nil reproduction helps in timing rodent control measures for optirum mortality. Carrying out rodent control during non breeding/low breeding sesons is not only cost effective but also slows down population rebuild. Thefollowing is the brief account of reproductive biology of major rodent pests in Karnataka:

1. The Indian mole rat *B.bengalensis:* Exhibit seasonal reproductive activity from early July till the end of April with an oestrus period between March and June. The peak reproductive activity was seen dung September to November. There was a correlation between breeding activity and rainfall with subsequent availability of food. The annual reproductive rate was 67 young/female/year. Thus the months of March, April, May and June are the best months to take up control measures against *B.bengalensis* when its population is at minimum (Srihari and Govind Raj, 1984).

2. The soft furred field rat, *M.meltada:* Breeding season was from July to early March and peak reproductive period was during September-November. The annual productivity was 53/young/female/breeding season. April to June (summer months, non breeding season) are ideal for initiating rodent control in fields infested with *M.meltada* (Govind Raj and Srihari, 1989).

3. The house rat, *R.rattus:* The breeding period extended from March to December. Peak reproduction was seen during September-November. The annual productivity was 70 young/female/year. It is recommended that rodent control in houses and poultry be taken up during January-February and in August (Sridhara and Krishnamurthy, 1992).

4. The Indian gerbil, *T.indica:* The peak reproductive activity was seen during October, November, December and was associated with availability of food after the monsoons. The breeding rate was 53 young/female/breeding season. The months of May, June and July are most suitable to initiate control operations against *T.indica* when its density is lowest and the species is not breeding (Govind Raj and Srihari, 1992).

5. The brown spiny mouse, *Mus platythrix:* The breeding period lasted from June to early March. The peak reproductive period was during September-November. The annual productivity was 54 young/female/breeding season. Sexual quiescence was seen during March and May coinciding with high temperature and scarcity of food. Thus the summer months of March, April and May are suitable for controlling *M. platythrix* (Govind Raj, 1994).

Table 4 depicts the panoramic picture of insect, disease and rodent pest complex of major food crops and important vegetable, horticultural and plantation crops. When compared with the damage inflicted as shown in tables 2 and 3, rodents cause significant losses to all these crops.

CONCLUSIONS

Since its inception the All India Coordinatied Research Project on Rodent Control at the University of Agricultural Sciences, Bangalore has generated enormous data on rodent species damaging major crops of Karnataka. The species are basically six to seven namely, *B.bengalensis, B.indica, M.meltada, T.indica, R.rattus, M.platytrhix* and *M.booduga*. What emerges is the pre eminent status of *B.bengalensis* as the number one pest in most of Karnataka. In some areas of northern Karnataka *T.indica* and *M.meltada* become predominant. Field mice are always minor pests. Coastal areas are characterized by *R.rattus* species in coconut, *F.tristriatus* in cocoa and hilly regions have *H.indica* and *B.indica* as additional conventional pests.

Burrow of *B. bengalensis* in ragi

Squirrel damage to chrysanthemum

Burrow of *B. bengalensis* in paddy

Burrow of *B. bengalensis* in cucumber

B. bengalensis burrow in French bean

B. bengalensis burrow in cabbage

Table 4 : Common insect, nematode, rodent pests and diseases of major crops of Karnataka.

Crop	Insect/Nematode Pests	Diseases	Rodent Pests
Rice	Yellow stem borer, Brown plant hopper, gollmidge, leaf folder, white backed plant hopper, thrips, root knot nematode, Rice root nematode.	Rice blast, sheeth blight, Bacterial leaf blight, sheath rot, brown rot, false smut.	*Bandicota bengalensis, Mus booduga, Millardia meltada*
Ragi	Ragi stem borer, white borer, aphids, thrips, leaf hopper, weevil, cutworm, black & red hairy caterpillars.	Blast, earhead smut, mosaic disease complex, wilt, downy mildew.	*Bandicota bengalensis, Millardia meltada, Tatera indica, Mus* spp.
Jowar	Shoot fly, stem borer, ear head bug, ear head midge, short bug, wingless grass hopper, jowar mite, aphids, caterpillars, pod borer, leaf folder, cutworm.	Grain smut, downy mildew, rust, sugary disease, leaf blight.	*Bandicota bengalensis, Millardia meltada, Tatera indica, Mus* spp.
Wheat	Pink stem borer, white ants, green plant bug, root grubs, army worm, surface grass hopper, aphids.	Rust, leaf spot, loose smut, wheat powdery mildew, wheat leaf blight.	*Bandicota bengalensis, Millardia meltada = Tatera indica, Mus* spp.
Maize	Pink stem borer, jowar stem borer, maize cutworm, cob caterpillar, root grub.	Downy mildew, leaf blight, common smut, rust.	*Bandicota bengalensis, Millardia meltada, Tatera indica, Mus* spp.
Sugarcane	Seedling borer, top shoot borer, green borer, pink borer, root grub, termites, sugarcane leaf hopper, mealy bug, black bug, aphids, jassids, grass hopper, hispa, Rhinoceros beetle, sugarcane smut, mites.	Red rot, whip smut, rust, blight, wilt, sugarcane mosaic virus, pineapple disease, gumming disease, ratton stunting, root knot nematode.	*Bandicota bengalensis, Millardia meltada, Mus booduga*
Red Gram	Pod borer, plume moth, pod fly, blister beetle, red headed hairy caterpillar, Tussock caterpillar, stink bug, pod bug, leaf miner, surface weevil, stem borer, pulse beetle, *tur* bud mite.	Wilt, sterility mosaic, leaf spot, powdery mildew.	*Bandicota bengalensis, Millardia meltada, Mus* spp. = *Tatera indica*
Soybean	Leaf miner, spider mite, pod borer.	Leaf spot	*Bandicota bengalensis, Tatera indica, Millardia meltada.*

Crop	Insect/Nematode Pests	Diseases	Rodent Pests
Groundnut	Groundnut leaf miner, plant lice, red headed hairy caterpillar, root grub, stem borer, thrips, cut worm, tobacco worm.	Tikka disease, rust, viral diseases, collar and root-not	*Bandicota bengalensis, Millardia meltada, Tatera indica, Mus* spp.
Sunflower	Corn-ear worm, black headed hairy caterpillar, surface weevil, semilooper, leaf hopper, binds.	Rust, leaf spot, collar not	*Bandicota bengalensis = Millardia meltada, Mus* spp.*Tatera indica.*
Potato	Potato tuber worm, greasy cut worm, lady bird beetle, aphids, ground grubs, leaf hopper, root knot nematode.	Late blight, Early blight, Brown rot or wilt, black scurf, viral diseases, mosaic symptoms, leaf roll.	*Bandicota bengalensis*
Tomato	Fruit borer, fruit sucking moth, white flies, mites, mealy bug, jassids, tobacco bug, cut worms, root knot nematode.	Damping off, leaf roll, leaf spot, late and early blight, bacterial wilt, powdery mildew, mosaic diseases, pink diseases.	*Bandicota bengalensis, Mus platythrix, Millardia meltada, Tatera indica, Mus booduga.*
Brinjal	Epilaehna beetle, aphids, jassids, mealy bugs, shoot fruit borer and stem borer, leaf weevil, leaf roller, bud worm, bugs, brinjal plume moth, red ant, caterpillars, leaf miner, termites, mites, root knot nematode	Damping off, little leaf disease, bacterial wilt, Fusarium wilt, Fruit rot, leaf spot, powdery mildew, broom rape.	*Bandicota bengalensis, Millardia meltada, Mus* spp. *Tatera indic.*,
Cabbage	Aphids, leaf webber, diamond back moth, cabbage butterfly, cabbage head borer, painted bug, cutworm, semilooper	Collar rot, damping off, black rot, club root, black leg, blight, fungal diseases, deficiency diseases.	*Bandicota bengalensis, Mus* spp. = *Tatera indica*
Cauliflower	SIMILAR TO CABBAGE		*Bandicota bengalensis, Millardia meltada, Mus booduga, Tatera indica*
Knol-Khol	SIMILAR TO CABBAGE		*Bandicota bengalensis, Millardia meltada, Tatera indica, Mus platythrix*
Beet Root	Aphids, cut worm, leaf webber, root knot nematode.	Leaf spot, rust, Heart rot.	*Bandicota bengalensis, Mus platythrix, Tatera indica.*
Carrot	Leaf hopper, aphids, weevil	Leaf blight, black rot, powdery mildew.	*Bandicota bengalensis, Mus platythrix.*
French Bean	Pod fly, aphid, pod borer, root grub, mites.	Yellow bean mosaic virus, Anthracnose, pot rot, rust, powdery mildew, ashy stem blight, angular leaf spot, bacterial leaf spot.	*Bandicota bengalensis, Mus platythrix, Millardia meltada*

Crop	Insect/Nematode Pests	Deases	Rodent Pests
Chow-Chow	Red pumpkin beetle, aphids, fruit flies, mealy bugs.	Downy milew, powdery mildew, mcaic diseases.	*Bandicota bengalensis, Millardia meltada, Mus platythrix*
Cucumber	Red pumpkin beetle, fruit fly, cut worm, root knot nematode.	Leaf spot.	*Bandicota bengalensis*
Sapota	Fruit borer, mealy bugs, scale insects and green bugs, hairy caterpillar, bud worm, anar butterfly caterpillar, thnps, mango hoppers, fruit fly.	Leaf spot, uity mold, leaf blight, flat lnb, fruit rot.	*Tatera indica = Bandicota bengalensis = Funambulus palmarum , Mus* spp.
Pomegranate	Fruit borer, thrips, aphids, castle pod borer, fruit fly, bark feeder, Tussock moth caterpillar, surface weevil, plug caterpillar, squirrels.	Canker an·die back, leaf spot, spacoma punicae, fruit crackig, fruit rot.	*Funambulus palmarum, Bandicota bengalensis, Millardia meltada, Mus* spp.
Guava	Scab, mealy bugs, scales, fruit sucking moths, fruit flies, bark eating caterpillars.	Wilt, anthrcnose, stem canker, sedling blight, white spot iseases, cercospor·eaf spot, zinc deficieny, ıarket disease, scab.	*Bandicota bengalensis, Millardia meltada = Tatera indica, Mus booduga*
Coconut	Eriophyid mite, Rhinoceros beetle, Red palm weevil, Black headed caterpillar, beetle, coried bug, mealy bug, root grub, scale insects, red spider mites, caterpillers, slugs, termites, aphids, red ants.	*Anabe rog.* leaf spot disease, Bd rot, Leaf rot, Root wilt, Sem bleeding, Gray bligh Thanjavore wilt.	*Rattus rattus, Bandicota bengalensis, Millardia meltada, Tatera indica, Mus platythrix.*
Cardamom	Hairy caterpillar, thrips, shoot borer, grass hopper, aphids, bugs, jassids, mites, fruit borer, beetles.	*Katte,* leaf pot, rust, foorki disease, dmping off, clump rot, af rot.	*Bandicota bengalensis, Tatera indica, Millardia meltada, Funambulus pennanti.*
Cocoa	Shot hole borer, mealy bug, pod mealy bug, pod borer, stem borer, aphids, thrips.	*Kole roga,* harcoal rot, black pod, ink disease.	*Funambulus tristriatus, Rattus rattus, Vandeleura oleracia.*
Areca Nut	Palm weevil, wood borer, arecanut borer, scale insects, aphids, thrips, red ants.	Bud rot, Mnali or *Kole roga*, Yello leaf, *Anabe roga,* stembleeding, Anthracnoe.	*Bandicota bengalensis, Millardia meltada = Mus booduga, Tatera indica,Funambulus palmarum*

VI. KERALA

Kerala state lies between 8°18' and 12°48' North latitudes and 74°52' and 77°22' East longitude as a long narrow strip of land with the width ranging only 32-130km in the South-Western corner of India, tucked between the western ghats on the east and Arabian sea on the west. The state has a geographical area of 38863 km² and a coastal line of 580km. (Ghosh, 1991).

AGROCLIMATIC ZONES (Fig. 1; Table 1)

Kerala state is divided into five agroclimatic zones namely, Northern Zone, Central Zone, High Altitude Zone, Problem Area Zone and Southern Zone.

Fig. 1 Agroclimatic zones of Kerala

1. NORTHERN ZONE : It comprises the four districts of Mallapuram, Kozhikode, Cannanore and Kasargod with a total coastline of 293km. Western ghats covered with forests gradually descend to coastal area with a series of hills, valleys intersected by rivers, streams, small lakes and back waters. Heavy rainfall occurs during June-July-August months with a mean of 3378 mm, the range being 2800-4000mm. Soil types vary from concretionary mass and massive laterite crest formations to saline, forest loam, riverine alluvial and coastal alluvial.

Major crops are coconut, paddy, cashew, rubber, pepper and tapioca. To a smaller extent banana, mango, jackfruit, vegetables, cocoa, cardamom, ginger and sesame are grown. The cropping system is mainly perennial. Mono crops

such as coconut, areca nut, rubber, pepper an cashew, perennial intercrops like coconut + areca nut, coconut + pepper, area nut + pepper + coconut, areca nut + coconut and annual crops like paddy-pady-paddy, paddy-paddy-vegetables, paddy-banana-yam and paddy-cowpea-black grm are cultivated.

2. CENTRAL DRY ZONE : The zone comprises he districts of Palghat, Trichur and Ernakulam excepting the coastal and hilly area. Rainfall consists of South-West monsoon from June to September and Nortwest monsoon from October to November. The range of rainfall is 3215-355mm. Soil types are identified as laterite, coastal alluvium, riverine alluvium, brwn hydromorphic, hydromorphic saline, black soil and forest loams.

Three cropping systems are in vogue - mno crops viz., rubber, tea, coffee, cashew, pineapple, coconut, areca nt, perennial intercrops i.e. coconut + vegetables/tuber crops/paddy/millet,coconut-pepper-areca nut, lemon grass + essential tree crops and annual crops nmely paddy-paddy-fallow, paddy-paddy/pulses/vegetables, paddy-paddy-paddy ad banana-vegetables-tuber crops.

3. HIGH ALTITUDE ZONE : It consists of high anges of Wyanad, Idukki, Palghat, Quilon and Trivendrum districts. The low rainall in January-March is conducive for the cultivation of coffee, rice, tea and peper. The other areas of the zone receive 1624-4000 mm rainfall. There are five tpes of soils namely laterite-Alfisol, well drained clay loam in Inceptisols, forest lam in Inceptisols, poorly drained deep soil in Entisols and Riverine alluvium-Entsols.

The three cropping systems are the usualperennial mono crops viz., coffee, tea, rubber, pepper, cardamom, perennial mixd crops i.e. coffee + pepper, food crops namely, paddy-paddy-paddy, paddy-banan, paddy-ginger, paddy-vegetables, tuber crops-oil seeds and annual crops such s cassava, ginger, banana, yam, garlic, vegetables and sugarcane

4. PROBLEM AREA ZONE : The zone lies alongthe coast of Kerala from Quilon in the south to Mallapuram in the north. It consistsof districts of Alleppey, Kottayam, Ernakulam, Trichur and Mallapuram. South-Wet monsoon extends from June to September and North-East monsoon from Ocober to November. The average rainfall is 3000mm. The zone faces the problm of floods during kharif and the problem of drought during later period of rabi. Sil is of four types namely, coastal alluvium, riverine alluvium, onattukara, alluviun and acid saline.

The cropping system is predominantly ric based and consists of rice-rice-sesame, tapioca-banana-yam, coconut-jackfruitmango/cashew intercropped with vegetables, yams, pulses, rice-rice-rice, rice wi coconut as boundary crop, rice-rice with coconut as boundary crop, rice-sesare, rice-rice-rice, rice-rice + fish and prawn + rice/prawn.

5. SOUHERN ZONE : This zone comprises districts of Trivendrum, Quilon, Pathanamthilta, Alleppy and Kottayam. South West monsoon extends from June to September while North-West monsoon occurs during October-November. Rainfall is exceptionally well distributed and averages 2246mm.

The soil types are laterite, with the texture varying from sandy to sandy loam and clay loam. The perennial mono crops are rubber, coconut, areca nut, pepper and cashew. Annuals include tapioca, banana, yam, ginger and turmeric while food crops cultivated are paddy-paddy, paddy-pulses, paddy-vegetables and paddy fallow.

PEST STATUS AND DISTRIBUTION OF RODENTS (Table 2 &3; Plate 6)

The rodent pests of plantation crops under AICRP on Rodent control were studied from 1978-1992. Mostly data was collected in and around the Central Plantation Crops Research Institute, Kasaragod which falls under northern zone of Kerala. The soil is coastal alluvial, reverine alluvial and forest loams with a rainfall range of 2800-4000mm. Although paddy based annual crops were cultivated, the data on rodent damage and species involved was collected only for perennial mono crops and perennial intercrops namely, coconut, areca nut and cocoa. Apart from species composition, there were studies on the ecology, biology and control of major pests. The cropwise rodent pests are as follows (Tables 2 & 3).

Table 1 : Agroclimatic zones, crop conditions and rodent pests of Kerala

Zone	District & Taluks	Soil type	Rainfall	Altitude	Cropping systems	Rodent pests
NORTHERN ZONE	Districts of Mallapuram, Kozhikode, Cannanore and Kasargod.	Hard crusty eroded, Coastal alluvial, Riverine alluvial, Forest loams	2800-4000mm June-Aug.		**Mono crops**: Coconut, areca nut, rubber, pepper & cashew.	*Cardamom: Rrw, Fpm, Bl, Ti*
					Perennial intercrops: Coconut + areca nut, Coconut +pepper, Areca nut + Coconut+Pepper, Areca nut+Cocoa.	Coconut: *Rrw, Ft, Fpm, Bl, Bb, Ti, Mb, Hi* Tapioca : *Rr, Vo* Arecanut: *Rr, Ft, Fpm, Mbb* Cashew :*Rr, Fpm, Rb, Bb, Hi* Rubber : *Bl* Oil plam : *Rr* Cocoa : *Rr, Ft, Fpm, Mbb*
					Annual crops: Paddy-Banana-Yam-Vegetables, Cowpea / Black gram	

Zone	District & Taluks	Soil type	Rainfall	Altitude	Cropping systems	Rodent pests
CENTRAL DRY ZONE	Seventeen taluks of Palghat, Trichur and Ernakulam Districts sans hills and coasts.	Laterite, Coastal, Alluvial, Riverine, Alluvium, Black soil, Forest loam	3215-3550mm June-Sept Oct-Nov	400-2000 above msc	**Monocrops**: Rubber, Tea, Coffee, Cashew, Pineapple, Coconut, Areca nut. **Perennial intercrops**: Coconut-Vegetables/Tuber crops/Paddy/millet, Coconut-Pepper-Areca nut, Lemon grass-essential tree crops. **Annual crops**: Paddy-Pulses/Vegetables. Banana-Vegetables-Tuber crops	NA*
HIGH ALTITUDE ZONE	High ranges of Wyanad, Idukki, Palghat, Quilon and Trivendrum Dts.	Laterite–Alfosoil, Clay loam, Forest loam, Brown-hydromorphic-Entisols, Riverine alluvium-Entisols	1624-4000mm June – Aug Jan – March	750m above msl	**Mono crops**: Coffee, Tea, Rubber, Pepper, Cardamom, **Mixed crops:** Coffee+Pepper, **Food crops:** Paddy-Banana, Ginger, Vegetables, Tuber crops-oilseeds. **Annual crops:** Cassava, Ginger, Banana, Yam, Garlic, Vegetables, Sugarcane.	NA*
PROBLEM AREA ZONE	Coastal taluks of Allepy, Kottayam, Ernakulam, Trichur and Mallapuram	Coastal alluvium, Riverine alluvium, Onattukara, alluvium, Acid saline, Sandy loam	3000mm average Jan-Sept. Oct-Nov		Paddy-Sesame-Fish-Prawn, Tapioca-Banana-Yam, Coconut mixed with Jackfruit/ Mango/ Cashew/ Vegetables, Pulses.	NA*
SOUTHERN ZONE	21 taluks belonging to Trivendrum, Quilon, Pathanamthitta, Allepy and Kottayam Dts.	Lateritic, Sandy-sandy loam, clay loam	2246mm average. Jan-Sept Oct-Nov		**Perennial mono crops** Rubber, Coconut, Areca nut, Pepper, Cashew. **Annuals**: Tapioca, Banana, Yam, Ginger, Turmeric. **Food crops:** Paddy-Pulses, Vegetables.	NA*

NA*-Not available ; *R.r.w. : R.rattus wroughtoni; Fpm : F. palmarum; B.i. B. indica; Tic.; T. india; B.b. : B. bengalensis, M b - M. booduga; Hi : Hytrix indica, V.o. : Vandeleuria oleracea.*

(a) Coconut: Several species of rodents including rats, squirrels, bandicoots, gerbils and porcupines damage coconut at every stage of cultivation. Four different subspecies of *Rattus rattus* are so far identified to damage coconut. These include *Rattus rattus wroughtoni, R.r.andamanensis, R.r.holechu* and *R.palliventer* (Advani, 1984 and 1985). Of these *R.r.wroughtoni* Hinton is the predominant species causing heavy damage to tender coconut in Kerala and Karnataka (Advani, 1984; Bhat, 1988; Bhat and Sujatha, 1989). Black rats also damage leaf stalks, unopened spathe, female flowers and mature nuts. *B.bengalensis, B.indica* and *Hystrix indica* were reported to damage shed nuts in the field. These burrowing rodents along with *T.indica* damaged coconut seedlings in the nursery.

Rodents are reported to cause 7.15 to 8.87% (Kurien, 2000) and 21-28.5% loss (Advani, 1985) to tender coconuts. Extent of damage was more when intercrops were cultivated (Advani, 1985). Damage was higher during summer and early monsoon (April-June) than during post monsoon (August-October). Typical rat damage consists of a small hole (5cm) near the perianth region (Plate 6). The damaged nuts fall down 2-6 days after attack (Bhat and Sujatha, 1989).

Table 2 : Damage of rodents to major crops of Kerala

Crop	Damage(%)	Rodent species composition
Rice	0.04-1.03	NA*
Coconut	7.15-8.87 (Kurian, 2000)	*Rrw, Ft, Fpm, Bi, Bb, Ti, Mbb, Hi*
	21-28.5 (Advani, 1984)	
Banana		NA*
Tapioca		NA*
Areca nut		*Rr, Vo*
Cocoa	75 (Advani, 1985)	*Rr, Ft, Fpm, Mbb*
Pepper		NA*
Ginger		NA*
Cashew		*Rr, Fpm, Rb, Bb, Hi*
Rubber		*Bi*
Oil palm		*Rr*
Cardamom		*Rrw, Fpm, Bi, Ti*
Cassava	12.05-28.47 (Kurian, 2000)	NA*

Rrw: Rattus rattus wroughtini; Ft: Funambulus tristriatus; Fpm: Funambulus palmarum; Bi: Bandicota indica; Vo: Vandeleuria oleracea; Bb: Bandicota bengalensis; Ti: Tatera indica; Mbb: Mus booduga booduga; Hi: Hystrix indica; Rr: Rattus rattus; Rb: Rattus blanfordi. NA*-Not available

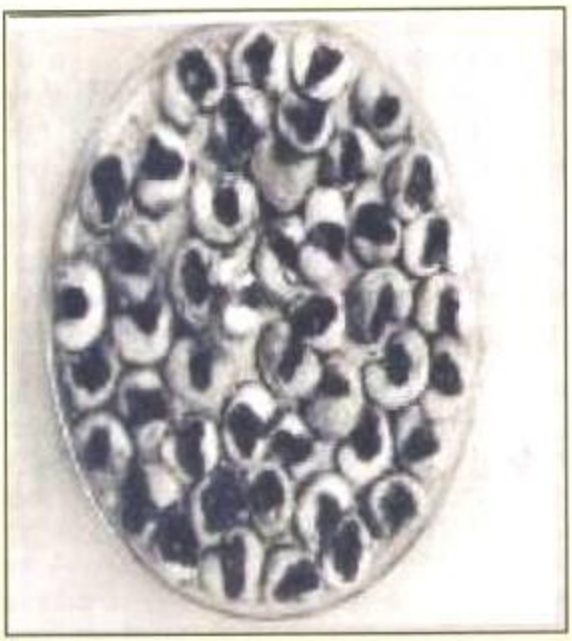
(b) Cocoa : It is grown either as a mixed crop along with coconut or areca nut or as a mono crop under forest along the west coast of Karnataka and Kerala. Rats and squirrels depredate on pods causing heavy damage which is variously reported to range from 8-15% and 18-47% (Bhat, 1993; Bhat *et al.*, 1981) and 75% (Advani, 1984). The species involved are *Rattus rattus* and *Funambulus tristriatus*. Rats gnaw holes near the peduncle, whereas squirrels gnaw oval holes in the center of the cocoa pod (Plate 6).

RODENT DAMAGE

Tender coconuts damaged by rat

Cocoa pods damaged by rodents

Arecanut damage by long tailed tree mouse



Cashew nuts damage by white tailed wood rat

Table 3 : Pests and diseases of major and minor crops in Kerala

Crops	Insects	Diseases	Rodents	Rodents likely to be present
Rice	Stem borer, Gall midge, Rice bug, Brown Plant Hopper, Leaf roller, Case worm, Swarming caterpillar, Rice hispa, Rice thrips, Mealy bug	Blast, Brown leaf spot, Narrow brown leaf spot, Sheath blight, Sheath rot, Stack burn, Bacterial blight, Grassy stunt, Ragged stunt.	NA*	*Bb, Mb, Mm*
Coconut	Eriophyid mite, Rhinoceros beetle, Red palm weevil, Black headed caterpillar, Cockchafer beetle, Coried bug, Mealy bug	Bud rot, Leaf rot, Root (wilt), Stem bleeding, Gray blight, Thanjavore wilt.	*Rrw, Ft, Fpm, Bi, Bb, Ti, Mbb, Hi*	
Banana	Banana aphid, Pseudo stem borer, Rhizome weevil, Nematodes	Bunchy top, Banana wilt, Sigatoka leaf spot, Kokkan	NA*	*Bb*
Tapioca	Tapioca scale, Mealy bug, Mites	Cassava Mosaic	NA*	*Bi, Hi, Bb*
Areca Nut	Spindle bug, Root grub, Mites, Inflorescence caterpillar	Bud rot, Mahali or Kole roga, Yellow leaf, Anabe roga	*Rr, Vo*	
Cocoa	Shot hole borer, Mealy bug	Vascular streak die back, black pod	*Rr, Ft, Fpm, Mbb*	
Cashew	Tea Mosquito, Stem and root borer	Anthracnose, Die back	*Rr, Fpm, Rb, Bb, Hi*	
Rubber		Powdery mildew, Pink disease, Leaf fall	*Bi*	

NA*-Not available

(c) Areca nut : These plantations are infested by *R.r.wroughtoni, F.tristriatus* and *V. oleracea*, (Bhat, 1982). They feed mainly on female flowers and tender areca nuts. Damage by *V.oleracea* is in the form of small round holes at the perianth portion (Plate 6). Nambiar (1949) had reported 20% damage to tender areca nuts in some areas of Assam and Karnataka.

(d) Cashewnut : *Rattus blanfordi* Thomas has been recorded as the pest of cashew nut (Bhat, 1989). This rat was observed to gnaw open the shells of cashew nut readily and feed on kernel (Plate 6). On average the rat consumes 5.7 nuts per day.

(e) Coconut-Cocoa-mixed plantation : The mixed plantations were infested by six species of rodents and one species of insectivore. *R.r.wroughtoni* was the most predominant species followed by *M.booduga* comprising 45% and 35% of population, respectively. The order of frequency of trapping of remaining rodents was: *V.oleracea* > *F.tristriatus* > *R.r.rufescens* > *Suncus murinus* > *T. indica*. *V.oleracea* was purely arboreal whereas, *F.tristriatus, R.r.wroughtoni and R.r.rufescens* were primarily arboreal but were also active on the ground. In contrast *M.booduga and S.murinus* were ground dwellers. At Hirehalli in Karnataka, coconut-cocoa plantations were infested by the south Indian palm squirrel, *F. palmarum*.

THE BIOLOGY AND LIFE HISTORY OF MAJOR RODENT PESTS OF KERALA

1. Rattus rattus wroughtoni Hinton, wroughton's rat is the most common rodent in South-west India and is a major pest of coconut and cocoa. In coconut plantations it lives mainly on the crowns of the palms by constructing nests either in the interspaces of nuts or in the spindle portion of the palm. They move from one palm to the other through fronds and rarely come to the ground (Bhat *et al.*, 1981). Damage to seedling of oil palm is also reported (Bhat *et al.*, 1990).

Studies on population ecology revealed male to female ratio of 0.8 to 1.0 with pregnant females present throughout the year but with two peaks, one in early summer (February-March) and the other during monsoon (July-August). The incidence of pregnancy was lowest in May when the day temperature was maximum. The litter size ranged 1-8. Home range was 1160 sq.m for males and 932.8 sq.m for females (Bhat *et al.*, 1987).

The most common food was male flowers of the coconut. Tender coconut husk and shell, cocoa, grass, seeds, small ants, grubs and certain insects were often eaten. Mosses, oil palm fruit, coconut kernel, beetles, ground roaches and caterpillars also formed a part of their diet occasionally (Bhat, 1991).

A ten fold numbers of rodents were captured on the crowns of coconut compared to ground level suggesting crown trapping and crown baiting are more effective in controlling rodent pests (Bhat and Sujatha, 1987).

2. Funambulus tristriatus Waterhouse, the Western ghat squirrel is a diurnal and arboreal rodent inhabiting West coast and the evergreen forests of Western Ghats. It is the second most abundant pest in coconut-cocoa cropping system, damaging mature and dried coconut. It is also a pest on cocoa and other fruit crops like mango, grapes, guava and sapota in the Western Ghats biome of Karnataka and Kerala. It is omnivorous consuming paddy grains, male flowers of coconut, termites, caterpillars, beetles and ants. Peak reproduction occurred during March, August and October (Bhat, 1982).

3. Mus booduga Gray, the little Indian field mouse is the second most predominant rodent found in coconut and cocoa plantations of Kerala. Population studies in plantations of inter-mixed crops of cocoa, banana, pineapple, black pepper, jack, leucaena, clove, nutmeg and lime revealed breeding activity throughout the year with a peak during September to November. Percent pregnancy was 21.8 and litter size varied from 2-8 (Bhat and Sujatha, 1991).

CONCLUSIONS

Plantation crops are predominantly gown in four out of the five zones in Kerala, the exception being Problem Area zone where the cropping system is rice based with coconut being grown as a majc, supplementary crop. All other zones have cropping systems based on plantatin crops mainly coconut, areca nut, cashew, rubber, pepper at lower altitudes and coffee, tea, rubber, pepper and cardamom at higher altitudes. The topograply, soil types, rainfall and other climatic conditions do not vary drastically amongs the five zones except high altitudes and coastal areas. Data on rodent speciescomposition and damage is generated only for the Northern zone which is indepthand exhaustive. Since the mandate of the kasaragod centre of the AICRP on roent control was to study the rodent problem in plantation crops, the data genrated at Northern zone may apply to other zones too. Towards this end the spcies composition of rodents infesting and causing damage to coconut, areca nut cocoa, cashew and rubber have been well documented. Based on data generated ı other similar agro-climatic conditions, the pest species are likely to be *B.bengalensis, M.booduga* and *M.meltada* in rice, *B.bengalensis* in banana, *B.indica, H.indica* ad *B.bengalensis* in tapioca and possibly no rodents in pepper and ginger (Table 3).Table 3 gives a cursory glance at the repertoire of insect pests, diseases and rodnts pests of major crops of Kerala.

VII. MADHYA PRADESH AND CHHATTISGARH

Madhya Pradesh and Chattisgarh lies almost in the centre of India between 17°26'N latitude and 74°84'E longitude. It is predominantly agrarian with 80 per cent of the population engaged in it. The catchment area of four major rivers of India, Yamuna, Ganga, Narmada and Godavari lay in these states. The land is highly diverse ranging from less than 50 m above MSL to 1200m above MSL. Soil types are alluvial, deep black, medium black, shallow black, mixed red and black, mixed red and yellow and skeletal soils.

CLIMATE

The mean rainfall is 1143mm varying from 800mm in northern and western parts to 1600mm in eastern districts and is received mostly during June to September.

CROPPING PATTERN

Irrigation is limited. Main cereals grown are wheat, rice, jowar, maize and minor millets. Important pulses are gram, black gram and red gram. Oil seeds grown are linseed, groundnut, sesame, rapeseed and mustard. Soybean is grown extensively.

AGROCLIMATIC ZONES

Twelve agro-climatic zones have been classified (Table 1, Fig. 1) which are described below.

1. CHATTISGARH PLAIN ZONE : The zone comprises most tehsils of Raigarh and Kanker tehsil of Bastar district. The rainfall is erratic and varies from 1300mm to 1600mm. The four soil types are blata, matasi, dorsa and kanhar. The major crops are rice, lathyrus, Kodon-kutki, linseed, wheat, black gram and gram. No commercial crops except limited cultivation of sugarcane. Mango, guava, banana, orange etc. are grown limitedly.

2. BASTAR PLATEU ZONE : It consists of Bastar division except the tehsil of Kanker. The land is undulating with slopes of varying magnitudes. Annual rainfall varies from 1200-1600mm. Temperature is stable and relative humidity is around 34%. Soil is loamy sand, sandy loam, silty loam in slopes and loamy to clayey in levelled areas. During kharif rice, Kodo-katki (minor millet), kulthi, maize, ragi, jowar, black gram and niger are grown. The rabi crops are rape, mustard, linseed, wheat, kulthi etc.

3. NORTHERN HILL ZONE OF CHHATTISGARH: This zone comprises of Surguja, Singrauli tehsils of Sidhi, Shehdol, Mandla, Joshpur and Dhamajaigarh tehsil of Raigarh. The climate is sub humid and the mean rainfall is 1455mm ranging from

Fig. 1. Agro climatic zones of Madhya Pradesh

1248mm to 1727mm. Mean minimum temperature is 17.5°C and mean maximum temperature is 33.2°C. Hilly regions are cooler. Topography of land is hilly and undulating consequent to differences in moisture retention which has resulted in the formation of different soil classes. These are upland unbounded, upland bounded, low land and extreme low land. In hilly areas, soils are stoney, coarse, red and yellow in colour. In upland fields, the soils are sandy reddish brown in colour. In low lying fields, soils are clay loam with good moisture retention capacity. The major kharif crops are rice, Kodo-kutki and maize. Mustard, gram and sesame are also grown.

4. KYMORE PLATEAU AND SATPURA HILL ZONE : the zone comprises of Jabalpur, Panna, Satna, Rewa, Swoni and Gopadbana, Deosar tehsil of Sidhi. Twenty seven percent of the land area is occupied by forests. The average rainfall ranges between 1200 to 1500mm. Soil is varying, ranging from mixed red and black to medium and deep black soils. Wheat is cultivated in largest area followed by paddy, gram and Kodo-kutkhi. Linseed, jowar, pigeon pea, sesame, rape and mustard are also grown.

5. VINDHYA PLATEAU RANGE : It comprises of parts of Guna, Damoh, Sagar, Vidisha, Bhopal, Raisen and Sehore districts. Soil is characteristic black soil, mostly medium in depth, a small proportion is deep black and shallow soil. Climate

Table 1 : Agro climatic zones, crops and rodent pest species of Madhya Pradesh

Zone	Districts/taluks	Soil type	Rainfall (Range/mm)	Crops/Cropping system	Rodent species
CHATTISGARH PLAIN ZONE	Durg, Raipur, Balaghat, Rajnandgaon, Bilaspur, Raigarh, Savangarh and Gharghoda *tehsils* of Raigarh and Kanker *tehsils* of Bastar.	*Blata Matasi Dorsa Kanhar*	1300-1600	Rice, *lathyrus*, *Kodo-kutki*, linseed, wheat, black gram, gram, sugarcane.	*Bb, Mm*
BASTAR PLATEAU ZONE	Bastar except Kanker *tehsil*.	Loamy sand, Sandy loam, Silty loam, loam, loamy to clayey	1200-1600	Rice, *Kodo-kutki*, Kulthi, maize, ragi, jowar, black gram, niger, rape, mustard, linseed, wheat.	NA*
NORTH HILL ZONE OF CHATTISGARH	Surguja, Singrauli *tehsil* of Sidhi, Shehdol, Mandla Joshpur, Dhamajaigarh *tehsil* of Raigarh.	Clay loam	1248-1727	Rice, *Kodo-kutki*, maize, mustard, gram, sesame	NA*
KYMORE PLATEAU AND SATPURA HILL ZONE	Jabalpur, Panna, Satna, Rewa, Seoni and Gopadhana, Deosar *tehsil* of Sidhi.	Mixed red & black, Medium & deep black	1200-1500	Wheat, rice, gram, *Kodo-kutki*, linseed, jowar, pigeon pea, sesame, rape and mustard.	*Mm, Rr, Mms, Fp, Bb, Mb, Ti*
VINDHYA PLATEAU ZONE	Chachora & Raghogarh *tehsils* of Guna, Damoh, Sagar, Vidisha, Raison, Gairatgunj, Begamgunj, Silwani, Goharganj & Udaipur *tehsils* of Raisen, Sehore, Ashta, Ichhawar, Nasullaganj *tehsils* of Sehora.	Black soil, Deep black & shallow.	1000-1200	Rice, wheat, sorghum & maize.	*Rr, Bb*
CENTRAL NARMADA VALLEY	Seoni, Malwa, Hoshangabad & Sohagpur *tehsils* of Hoshangabad, Narasinghpur & Budhmi *tehsils* of Sehore, Bavelli *tehsil* of Raisen.	Deep black, clay.	1000-1200	Pulses, *arhar* & red gram, wheat, soybean, minor millets, cotton.	*Mm, Bb, Rr*

Zone	Districts/taluks	Soil type	Rainfall (Range/mm)	Crops/Cropping system	Rodent species
GRID ZONE	Bhind, Morena, Gwalior, Shivpuri, Kalaras, Pohri *tehsils* of Shivpuri, Mungdi & Ashoknagar *tehsils* of Guna.	Alluvial, Medium black, Mixed red & black, Red & yellow.	566-977	Rice, wheat, sorghum, pearl millet, maize, rape seed, mustard.	NA*
BUNDELKHAND ZONE	Datia, Tikamgarh, Chattoorpur, Karera & Pachore *tehsils* of Shivpuri and Guna *tehsils* of Guna.	Clay, clay loam, Sandy loam	750-1100mm	Wheat, gram, jowar, sesame, barley, paddy, minor millets, black gram, soybean, ginger, sugarcane, potato.	NA*
SATPURA PLATEAU ZONE	Chindwara, Betal	Reddish brown to black clay loam.	700-1400	Rice, wheat, sorghum, maize.	*Rr, Bb, Mm, Mms, Fp*
MALWA PLATEAU ZONE	Mandsaur, Rajgarh, Ujjain, Indore, Dewas, Dhar, Badnawar & Sardarpura *tehsils* of Dhar, Shajapur, Rattam & Pettwad *tehsils* of Jhabua.	Medium black, Deep black, Shallow soil, (Sandy clay loam)		Sorghum, maize, soybean, gram, wheat.	*Rr, Mm, Mus sp.*
NIMAR VALLEY ZONE	Nimar, Harda *tehsil* of Hoshangabad, Manawar *tehsils* of Dhar.	Shallow deep	Uncertain	Cotton, sorghum, rice, wheat, pearl millet, maize, black gram, groundnut.	NA*
JHABUA HILL ZONE	Jhabua, Thobat, Jobat, Alirajpur *tehsils* of Jhabua, Kukshi *tehsil* of Dhar.	Skeletal soil, shallow (clay to clay loam), Black soil	600-800	Maize, jowar, black gram, brinjal, gram, groundnut.	NA*

NA*-Not available

is sub tropical and annual rainfall is 1000 to 1200mm. Summers are very hot and winters are very cold. Crops cultivated are rice, wheat, sorghum and maize.

6. CENTRAL NARMADA VALLEY : The valley region consists of parts of Hoshangabad, Sehore and Raien districts. Soils are mainly deep black with 40-60% clay. Rainfall range is 1000-1200mm. Pulse cultivation dominates kharif and rabi with arhar in the former, gram and red gram in the latter. In the wheat belt, kharif soybean is followed by rabi wheat. Minor millets, cotton are also grown considerably.

7. GRID ZONE : It consists of parts of Shivpuri and Guna districts. Most of the soil is of alluvial group falling into alluvial, medium black, mixed red and black, and red and yellow soil. Average rainfall is 738mm, range being 566 to 977mm.

Major crops are rice, wheat, sorghum, pearl millet and maize. Considerable area is under the cultivation of rape seed, mustard and pulses.

8. BUNDELKHAND ZONE : The Bundelkhand region comprises of many tehsils of Shivpuri and two tehsils of Guna. The elevation of the zone varies from 266m to 560m above MSL. The topography of the zone is characterised by flat land, small percentage of slope and hillocks. Soil variety comprises of clay, clay loam and sandy loam. Rainfall ranges from 750mm to 1100mm. Minimum temperature is 4.5°C and maximum is 43°C. Wheat, gram and jowar are the major crops of the zone followed by sesame, barley, paddy, minor millets and black gram. Soybean, ginger, betelvine, sugarcane, potato, turmeric, colocasia, sweet potato etc. are also grown.

9. SATPURA PLATEAU ZONE : It comprises Chindwar and Betul districts. The total area under forest is about 31%. The soils vary from light reddish brown to black clay loam. Crop cultivation almost entirely depends on rain. The range of rainfall is 700-1400mm. Rice, wheat, sorghum and maize are the major crops.

10. MALWA PLATEAU ZONE : It comprises of Mandsaur, Rajgarh, Ujjain, Indore, Dewas, parts of Dhar and Jhabua districts. The zone lies 450-675mm above MSL Hilly and mountainous, surrounded by Vindhyan range on the south, east and west. Soil is mostly medium black. Deep black and shallow soils are also common. Soils are mostly heavy with sandy clay loam to clay texture. Rainfall varies from 800-1200mm. Sorghum, maize and soybean are the major crops during kharif while gram and wheat are cultivated during rabi.

11. NIMAR VALLEY ZONE : It includes parts of Nimar, Hoshangabad and Dhar districts. Land is undulated, soil is shallow in nature and rainfall is uncertain. Cotton is the most important crop. Sorghum is cultivated in maximum area. Rice, wheat, pearl millet, maize, black gram and groundnut are also grown.

12. JHABUA HILL ZONE : It comprises of parts of Jhabua and Dhar districts lying at an altitudinal range of 450-700m above MSL. The climate is arid to sub arid with an annual rainfall of 600-800mm. The minimum temperature is 10°C and the maximum goes upto 41°C. Due to rolling topography most of the soil is shallow and is classified as skeletal soil. Soil is generally gravely and brownish. The texture is clay and clay loam. Black soil characterises valleys. Maize is the most cultivated crop, followed by jowar, black gram, Bengal gram and groundnut. Cotton is cultivated in black soil.

DISTRIBUTION OF RODENT PEST SPECIES IN MADHYA PRADESH AND CHHATTISGARH (Table 2)

Data has been generated for six agro climatic zones of the state. The species diversity is maximum in Kymore plateau and Satpura hill range. The paddy-wheat region of the zone was infested by *M.meltada, R.rattus, M.musculus, F.pennanti, B.bengalensis, M.booduga* and *T.indica*. while the jowar-wheat zone was less

species rich with five species of rodentsnamely, *R.rattus, B.bengalensis, M.musculus, M.meltada* and *F.pennanti*. In thepaddy-moong-wheat belt of Vindhya plateau only two species were recorded namly *R.rattus* and *B.bengalensis*. The paddy-soybean cultivation in Malwa plateau ɜigon was infested by *R.rattus* and *M.meltada*. Paddy in Chattisgarh plain zone ɾas damaged by *B.bengalensis* and M.meltada. Three species namely, *M.meltaa, B.bengalensis* and *R.rattus* were reported for Central Narmada valley. The cottn-jowar belt of Malwa-agro climatic zone was infested by *M.meltada* and *Mus* spcies.

PEST STATUS OF RODENTS AND CROPS VISE DAMAGE (TABLE 3)

(a) Wheat : The crop was infested by *B.begalensis* during the early stages of study (1983-1989) and by *M.meltada* in late stage (1991-92). During 1997-98 three species viz. *M.meltada, B.bengalensis*and *M.booduga* were observed to damage wheat crop. The damage to crops roorted was 90.45kg/ha and 5.01% during 1991-92 and 1997-98, respectively.

(b) Rice : Fields were intested by *B.bengalensis*only during 1985-86 and by *R.rattus* and *B.bengalensis* in 1988-89. *B.bengalensis,R.rattus* and *M.booduga* were seen in 1991-92 while in later years (1997-98) onl *M.meltada* and *B.bengalensis* were observed. Damage ranged 1.5 to 19.03% yiel loss and varied over the years.

(c) Groundnut : The crop was damaged by *.pennanti* and *M.meltada*. Squirrels damaged the sown seeds upto 16.89%. Danage was inflicted from sowing to harvest stage and was 13.4% in 1983-84.

(d) Gram : It was infested by *B.bengalensis,R.rattus* and *M.meltada. S.murinus* was also trapped. Maximum yield loss was 1i-16.5%.

(e) Sugarcane : The sugarcane was damagecin the range of 1.66 to 8.77% by *B.bengalensis*.

(f) Soybean : It was damaged more in perphery than in centre by *R.rattus, B.bengalensis* and *M.meltada*. The yield loss ɾas 28.61% and 44.8 kg/ha.

(g) Opium: The husk was damaged significarly more than the seed. *M.booduga* and *M.meltada* were the pests damaging thecrop.

(h) Potato: *B.bengalensis* and *M.meltada* hoaded 7.89 kg/ha in their burroows.

(i) Chick pea: *B.bengalensis* and *M.meltada* cused an yield loss of 2.79%.

(j) Mushroom: Apart from feeding on sɐwn and mushroom, there was contamination of mushroom with hair and facal pellets of rats.

(k) Cactus: *B.bengalensis* burrowed under thebush and sliced the branches.

(l) Tomato: 10kg/burrow was hoarded by *B.bngalensis*.

Table 2 : Rodent species distribution and composition in selected agro-climatic zones of Madhya Pradesh (Anon, 1983-84, 85-86, 86-87, 88-89, 91-92, 95-96 & 97-98)

Agro climatic zones	Place/districts	Associated crops	Rodent species
KYMORE PLATEAU & SATPURA HILL ZONE	Jabalpur Kundan *tehsil*. Katangi Rewa	a. Paddy-Wheat Soybean	*Mm, Rr, Mms, Fp, Bb, Mb, Ti* *Mms>Rr>Fp.* *Bb* *Bb>Rr*
		b. Jowar-Wheat zone	*Rr=Bb>Mm, Mms, Fp*
VINDHYA PLATEAU RANGE	Sehore	Paddy, *Moong*, Wheat	*Rr>Bb*
MALWA PLATEAU REGION	Shahpur	Paddy, Soybean	*Rr>Mm*
CHATTISGARH PLAIN ZONE	Balaghat	Rice	*Bb>Mm*
CENTRAL NARMADA VALLEY			*Mm, Bb, Rr*
MALWA-AGRO CLIMATIC ZONE		Cotton-Jowar	*Mm>Mus*

Table 3 : Rodent damage to crops in Madhya Pradesh

Crop	Damage (%/YL)	Species	References
Wheat	27% tillers	*Bb*	Anon 1983-84
	9.6-20.2g/m^2	*Bb*	Anon 1988-89
	10.45kg/ha.	*Mm*	Anon 1991-92
	5.01%	*Mm, Bb, Mb*	Anon 1997-98
Paddy	YL 19.03%	*Bb*	Anon 1985-86
	YL 1.5-8.8%	*Rr, Bb*	Anon 1988-89
	YL 2.45-3.6%	*Bb, Rr, Mb*	Anon 1991-92
	4.81%	*Mm, Bb*	Anon 1997-98
Groundnut	13.4% sowing to harvest	*Fp, Mm*	Anon 1983-84
	4.6 to 9.8%		
	16.89%	*Fp*	Anon 1985-86
Gram	0.6% to plants	*Mm>Bb>Sm*	Anon 1983-84
	YL 14-16.5%	*Bb*	Anon 1986-87
	2.5%	*Bb, Rr, Mm*	Anon 1988-89
Sugarcane	1.66-8.77%	*Bb*	Anon 1985-86
Soybean	YL 28.54% in periphery	*Rr, Bb, Mm*	Anon 1985-86
	YL 12.46% in the centre		Anon 1986-87
	YL 28.61%	*Rr, Bb*	Anon 1988-89
	YL 9.3%, 44.8kg/ha	*Rr, Bb*	Anon 1991-92
Bengal gram		*Bb*	Anon 1985-86
Opium	Latex – 0.9 Seed – 0.82 Husk – 8.6 g/m^2	*Mm, Mb*	Anon 1991-92
Potato	7.89kg hoarded/ha.	*Bb, Mm*	Anon 1995-96
Chick pea	YL 2.79%	*Bb, Mm*	Anon 1997-98
Mushroom	Damage to mushroom and spawn; contamination of grown mushroom	*Rr*	Thomas *et al*., 1995
Cactus	Branches cut	*Bb*	Thomas, 1998
Tomato	10.5kg/burrow hoarded	*Bb*	Thomas *et al*., 1986

CONCLUSIONS

The Madhya Pradesh unit of AICRP on odent control was functional from 1983 to 2001 operating from Jawaharlal Krisi Vidhyalaya, Jabalpur. The species composition of rodents was studied in six ou of the twelve agro-climatic zones. *B.bengalensis, M.meltada* and *R.rattus* were he predominant species damaging various crops in Madhya Pradesh. The surpsing observation is prevalence of *R.rattus,* basically a commensal rodent infesng and damaging cultivated crops in most of the zones studied. *M.musculus, F.penanti* and *M.booduga* also occurred but to a lesser extent. Cereals, pulses andhorticultural crops were damaged significantly. The consumption of sown grondnut seeds by *F.pennanti* is an interesting but an alarming phenomenon.

VIII. NORTH EAST HILL REGION

The North Eastern Hill Region comprises the States of Manipur, Meghalaya, Nagaland, Sikkim, Tripura, Arunachal Pradesh and Mizoram (Fig.1) lying between 21.5° and 29.5° N latitudes and 85.5°- 97.5° E longitudes and representing a distinct agro-climatic area of our country. Assam is situated in the centre and hill states (excepting Sikkim), are situated around it.

CROPPING PATTERNS

In NEH region, rice-rice, rice-potato, maize -potato, potato-potato are the promising cropping systems. Inter cropping of legumes with main crop gives additional income without affecting the yield of main crop. Similarly in summer, the inter-cropping of potato, soybean and maize fetches extra yield.

Earlier mono cropping with low yielding varieties of rice and maize was the common practise in NEH Region. Now double and triple cropping systems have been developed for upland and wetland areas.

Shifting cultivation or locally known as Jhum cultivation is one of the main systems of cultivation practiced in the region. The second system of Jhumming is the Bun cultivation, which is practised in East and West Khasi Hills and Ri-Bhoi district of Meghalaya for cultivating potato, sweet potato, ginger, vegetables etc.

AGRO-CLIMATIC ZONES

The entire North-East Hill Region has been divided into six distinct agro-climatic zones namely, Alpine Zone, Temperate and Sub-Alpine Zone, Sub-Tropical Hill Zone, Sub-Tropical Plain Zone, Mild Tropical Hill Zone and Mild Tropical Plain Zone.

1. ARUNACHAL PRADESH: Climate ranges from sub-tropical to extreme alpine type. The normal mean minimum and maximum temperature vary between 18 to 24°C in summer and 9.0 to 17.7°C in winter. Heavy fog is common over the mountain area of the State during most of the year. The temperature in the snow-clad mountain remains -7°C during winter.

2. MANIPUR : The State has moderate climate but great variations are seen in hills and valleys. The average annual rainfall of the state is 2076 mm. The temperature varies from 19.8 to 28.7°C in summer and 9.9 to 23.9°C in winter.

3. MEGHALAYA : The upper plateau of Meghalaya has per-humid climate with more than 2500 mm of annual precipitation. The Cherrapunjee-Mawsynram range receives around 11500 mm of annual rainfall. In plateau area, the average temperature varies from 19.0 to 26.3°C in summer and 11.5 to 22.0°C in winter. The Eastern parts of the State have moderate summer but severe winters.

4. MIZORAM : The temperature varies from 16.5 to 29.5°C in summer and 10.6 to 26.1°C during winter. Being predominantly hilly, the state has moderate climate with average rainfall varying from 1600 to 2200 mm.

Fig. 1. States of North-Eastern Hill region ad distribution of rodent species

5. NAGALAND : The state has varied type of climate ranging from sub-tropical in Dimapur area to sub-temperate. The average temperature in Dimapur sub-division is around 37°C. Annual rainfall of the state vaes from 1500 to 2100 mm.

6. SIKKIM : The extreme variation in elevation ccounts for various type of climatic conditions. The areas below 600m elevation have humid mild tropical climate. However, low temperature prevails in areas lyig between 2000 to 6000 m above M.S.L. The areas falling above 5000m elevatio have perpetually snow-clad peaks. The average temperature in the state varies frm 17 to 26.2°C in summer and 9.1 to 20.2°C in winter. The state has an averagerainfall of 3000 mm annually.

7. TRIPURA : The state has a typical monsoortype of climate. The foothill plains, valleys and hills have different type of climate The average annual rainfall of the State varies from 1500 to 2500 mm and aveage temperature extends from 15.5 to 32.0°C during the year.

Soil types of entire region are acidic caued by high rainfall and leaching of bases to lower horizons which results in por plant growth.The soils of these hilly state are classified into five orders viz., Alsols, Entisols, Inseptisols, Mollisols, Ultisols.

RODENT SPECIES, THEIR COMPOSITION,DISTRIBUTION AND SEASONAL ACTIVITY

The North Eastern Hill Region of India is ull of green vegetation and bamboo forests. These forests have various agro-eological systems of which jhum cultivation is most important. Rodents cause eavy losses to agricultural crops in

Table 1 : Rodent damage to crops and species involved in NEH region (Pathak and Kumar, 2001)

Crops	*Kharif*	
	% damage	Rodent species
1. Paddy		*B.bengalensis*
(a) Low land	4.6-16.8	*R.rattus*
(b) Upland	3.9-12.9	*M.booduga*
2. Maize	3.55-22.2	*B.bengalensis* *R.rattus*
3. Pine apple	2.6-20.3	*B.bengalensis* *R.rattus*

fields and storage in this region. They are known to create famine like situation in Mizoram and Arunachal Pradesh during the time of cyclical bamboo flowering. The next cyclical bamboo flowering is expected in the year 2007.

In all the seven states of NEH region, rice and maize are the major crops during kharif; mustard, cole crops and vegetables during rabi and summer. The main vegetables grown are pea, broad bean, potato and brinjal. Damage estimates are available only for rice, maize and pine apple (Table 1). Low land paddy was damaged at 4.6 to 16.8% and damage to upland paddy was 3.9-12.9%. The species causing damage were *B.bengalensis, R.rattus* and *M.booduga*. The range of damage to maize was 3.9-12.9% and the species involved were *B.bengalensis* and *R.rattus*. The two species caused 2.6 to 20.3% damage to pine apple (Pathak and Kumar, 2001).

A survey conducted in all the states of NEH Region revealed that rodent activity was highest in the areas where livestock and poultry are raised (Fig. 2). This may be due to the presence of large quantity of nutritious feed round the year. Highest numbers of active burrows were recorded in upland cultivated areas and Jhum fields, lowest density was seen in lowland cropped area and wastelands (Fig. 2).

Fifteen species of rodents were recorded from North Eastern Hill Region, belonging to the genus *Rattus, Bandicota, Mus, Cannomys, Vandeleuria* and *Callosciurus*. *B. bengalensis* is the predominant species followed by *R. nitidus, M. musculus* and *R.rattus*. The altitudinal distribution of rodents in the different states is presented in Table 2 (Pathak and Kumar, 2001). *B.bengalensis, R.rattus, R.nitidus* and *M.musculus* were recorded at all the altitudes varying from 0.0 to 5000m above MSL in all the states of NEH Region. *Canomys badius badius* was limited to lower altitude i.e. 0-500m above MSL. Five species viz., *R.r.tistae, B.indica nemorivaga, M.cervicolor* and *C.pygerithrus* were seen at 501-1000m abvoe MSL. Seven species namely, *R.r.khyensis, R.norvegicus, R.nitidus, R.niviventer, R.bowersi, M.booduga* and *V.oleracia* were found from 501 to 5000m above MSL.

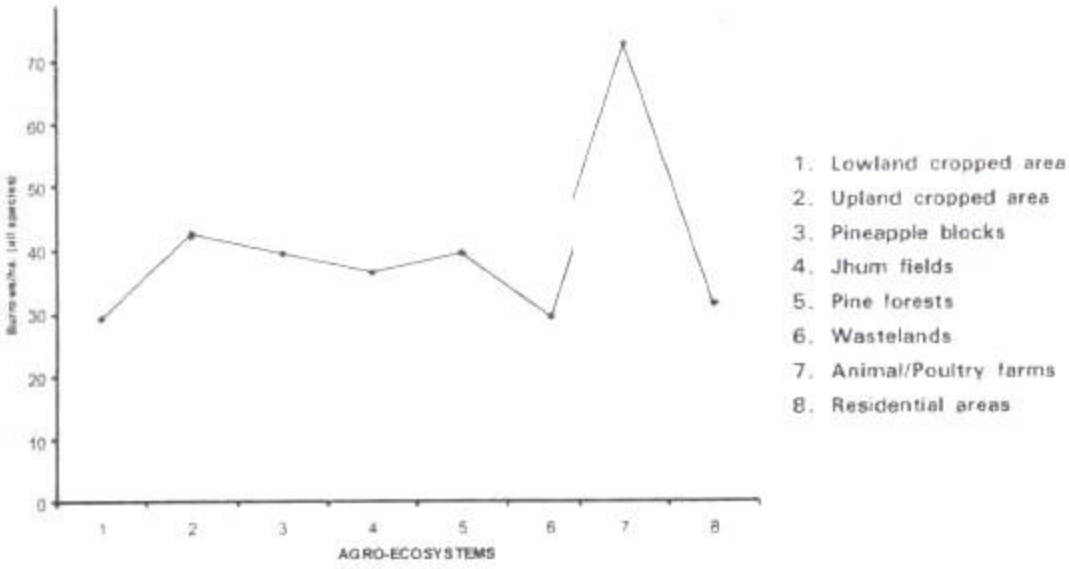


Fig. 2. Status of active burrows in differentagro-ecosystems (Av. of 10 years: 1983-193)

Table 2 : Distribution of rodent species at different altudes

Species	Altitude (m above MSL)		
	Lowr (0.0–00)	Medium (501–1000)	High (1001-5000)
1. *Rattus nitidus nitidus*	R	R	R
2. *Rattus rattus*	R	R	R
3. *Rattus rattus khyensis*	NR**	R	R
4. *Rattus rattus tistae*	NR	R	NR
5. *Rattus norvegicus*	NR	R	R
6. *Rattus niviventer*	NR	R	R
7. *Rattus bowersi*	NR	R	R
8. *Bandicota bengalensis*	R	R	R
9. *Bandicota indica nemorivaga*	NR	R	NR
10. *Cannomys badius badius*	R	NR	NR
11. *Mus musculus*	R	R	R
12. *Mus booduga*	NR	R	R
13. *Mus cervicolor*	NR	R	NR
14. *Vandeleuria oleracia dumaticola*	NR	R	R
15. *Callosciurus pygerithrus*	R	R	NR

*R: Recorded **NR: Not recorded

The highest density of *B.bengalensis* (B/ha.) was recorded during July-September (Fig. 3). The rodent activities stated increasing from March onward when the crops and vegetation were availableand reached the peak between July to October at crop maturity stage. Density of odents was low between December and February (Fig.2).

Table 3 : Relative distribution of rodent pests in the NEH region

State	Rodent species composition		
	Major	Minor	Crops/Facilities Affected
Arunachal Pradesh	*Rattus nitidus* *Rattus rattus* *Mus musculus*	*Rattus rattus tistae* *Bandicota Bengalensis* *Vandeleuria oleracea*	Rice, Maize, Tuber crops and Fruits Godowns & Houses
Manipur	*B.bengalensis* *M.musculus* *R.nitidus*	*R.rattus* *R.r.tistae*	Rice, Maize
Meghalaya	*B.bengalensis* *R.nitidus* *M.musculus* *R.rattus*	*R.norvegicus* *R.r.tistae* *R.niviventer* *B.indica*	Rice, Maize, Groundnut, Soybean, Sweet potato, Pineapple Godowns & Houses
Mizoram	*M.musculus* *R.rattus*	*R.nitidus* *M.booduga* *B.bengalensis* *R.norvegicus* *C.pygerythrus* *R.r.tistae*	Rice, Maize, *Jhum* crops Godowns & Houses
Nagaland	*R.rattus* *B.bengalensis* *M.musculus*	*C.badius badius* *R.nitidus*	Paddy, Maize, Tuber crops, Pineapple, *Jhum* crops
Sikkim	*R.nitidus* *M.musculus* *R.rattus* *B.bengalensis*	*R.r.tistae* *M.booduga*	Paddy, Maize, *Jhum* crops
Tripura	*M.musculus* *B.bengalensis* *R.rattus*	*R.nitidus* *R.r.tistae* *C.pygerythrus*	Paddy, Tuber crops, Maize, Pineapple, *Jhum* crops, Godowns
Over all	*B.bengalensis* *Rattus nitidus* *Mus musculus* *Rattus rattus*	*Rattus nitidus* *R.r.tistae* *Rattus niviventer* *Bandicota indica*	

THE STATE WISE DISTRIBUTION OF RODENT SPECIES IN NEH REGION IS AS FOLLOWS (Table 3; Plate 7).

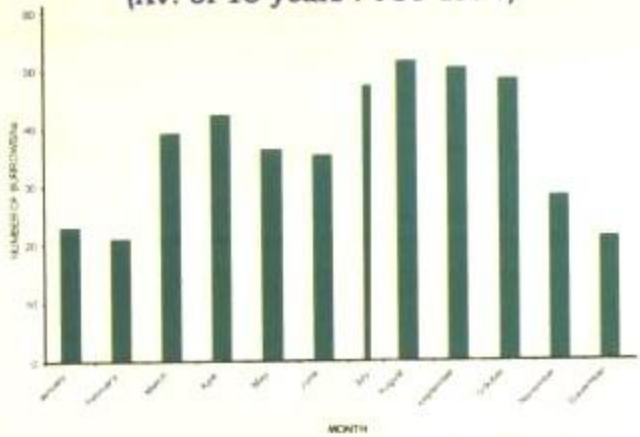
(a) Arunachal Pradesh: The major species are *R.nitidus, R.rattus, M.musculus., R.r.tistae* and *B.bengalensis*. *V.oleracia occur* to a lesser extent.

(b) Manipur: *B.bengalensis, M.musculus* and *R.nitidus* are the major species. The two *Rattus* species, *R.rattus* and *R.r.tistae* are the minor species.

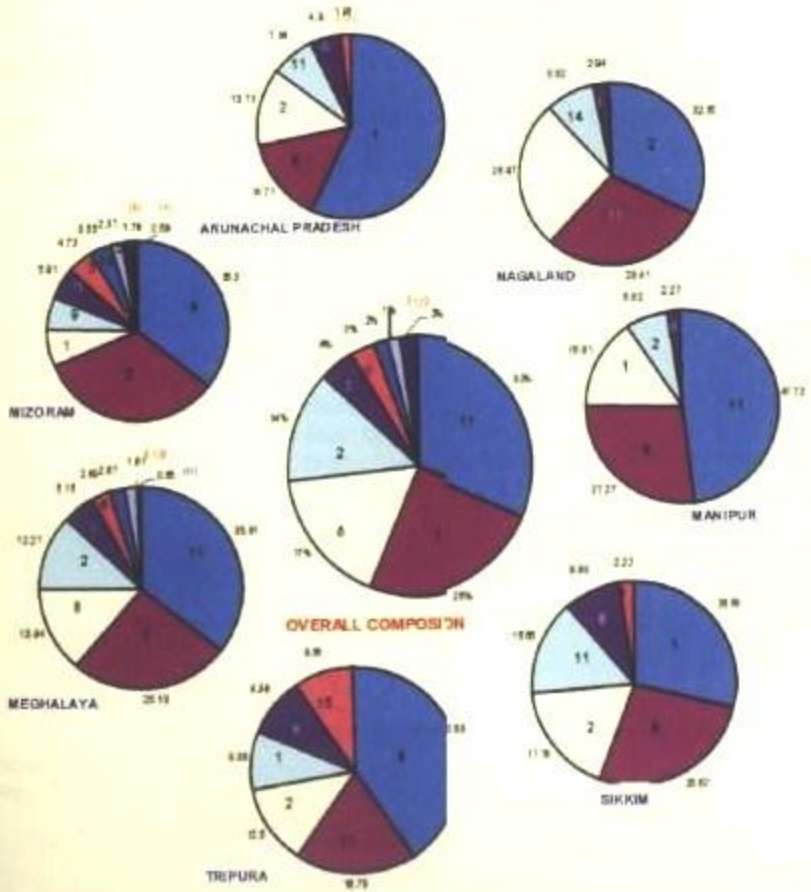
(c) Meghalaya: *B.bengalensis, R.nitidus, M.musculus* and *R.rattus* occurred more than *R.norvegicus, R.r.tistae, R.niviventer* and *B.indica*.

(d) Mizoram: Only two species occurred in very large numbers namely, *M.musculus* and *R.rattus*. The minor species were *R.nitidus, M.booduga, B.bengalensis, R.norvegicus, C.pygerythrus* and *R.r.tistae*.

Monthwise rodent densit of *B. bengalensis*
(Av. of 10 years : 983-1993)



Species composition of rdents in NEH region



1. *Rattus nitidus* 2. *Rattus rattus* 3. *Rattusnorvegicus* 4. *Rattus rattus khyensis* 5. *Rattus bowersi* 6. *Rattus rattus tistae* . *Rattus nivienter* 8. *Mus musculus* 9. *Mus booduga* 10. *Mus cervicolor* 11. *Bancota bengalensis* 12. *Bandicota indica nemorivaga* 13. *Vandeleuria oleracea dunticola* 14. *Cannomys badius badius* 15. *Callosciurus pygerythrus*

(e) Nagaland: Three species of rodents viz., *R.rattus, B.bengalensis and M.musculus* are major pests. The minor pests are *C.badius badius* and *R.nitidus.*

(f) Sikkim: *R.nitidus, M.musculus, R.rattus* and *B.bengalensis* are the major species. Only two species were minor viz., *R.r.tistae* and *M.booduga.*

(g) Tripura: *M.musculus, B.bengalensis* and *R.rattus* are the major species and the minor species are *R.nitidus, R.r.tistae* and *C.pygerythrus.*

(h) Major species: *Bandicota benglensis* is the predominant species (31.57%) followed by *Rattus nitidus* (24.51%), *Mus musculus* (16.88%) and *Rattus rattus* (14.35%). These species are causing considerable damage in the fields as well in houses and godowns

(i) Minor species: *Rattus norvegicus, Rattus rattus tistae, Rattus niviventer* and *Bandicota indica nemorivaga* constitute 4.48%, 2.91%, 2.05% and 1.29% of the total population, respectively.

Other species viz., *Mus booduga, Callosciurus pygerithrus, Mus cervicolor, Vandeleuria oleracea dumaticola, Rattus bowersi, Cannomys badius badius* and *Rattus rattus khyensis* constitute 1.96% of the total population (Plate 7).

The pest and disease complex of major crops of Meghalaya is presented in

Table 4 : Pests and diseases of major crops in Meghalaya

CROP	MAJOR PESTS	MAJOR DISEASES	RODENT PEST SPECIES
PADDY	Stem borer, Gundhi bug, leaf folder and rice root aphid	Blast and leaf spot	*B.bengalensis*
MAIZE	Cob borer and stem borer	Turcicum blight	*B.bengalensis, R.rattus, M.booduga*
LEGUMES	Leaf folder, blister beetle	Angular Leaf spot	*B.bengalensis*
SOYBEAN	Leaf folder, stem fly	Soy bean rust	*B.bengalensis*
GROUNDNUT	Leaf folder, blister beetle	Tikka and rust	*B.bengalensis R.nitidus*
POTATO	PTM, cut worm	Early and late blight	None
SWEET POTATO	Weevil, tortoise beetle, leaf feeding caterpillars	Leaf spot and antracnouse	*R.nitidus and B.bengalensis*
PINE APPLE	Mealy bug		*B.bengalensis R.nitidus R.rattus*
GINGER	Stem borer weevil and lepidopteran borer		None
FORESTS	Eurostyles punctigera		
1. *Micahelia champaka*	bug		NA*
2. *Gmalina orborea*	Craspedonta Leyana beetle		
PASTURES	-	-	*V.oleracia*
WASTE LANDS			
ANIMAL/POULTRY SHEDS	Ticks and mites	Diarrhea, Foot & Mouth diseases	*M.booduga, R.rattus, B.bengalensis*

NA*-Not available

Table 4. *B.bengalensis* was the sole rodent species damaging paddy, legumes and soybean. *B.bengalensis* and *R.nitidus* infested groundnut and sweet potato fields. *M.booduga, R.rattus and B.bengalensis* were found in maize and live stock facilities like animal and poultry sheds. *B.bengalensis, R.nitidus* and *R.rattus* damaged pine apple. Only *V.oleracia* was recorded from pastures and wastelands.

In recent years it has been observed that the population of *Rattus rattus* and *Rattus nitidus*, which were the predominant species in residential areas and fields, respectively, are continuously decreasing in comparison to previous years. Simultaneously *B.bengalensis* is establishing its predominance in residential areas as well as in fields.

BAMBOO FLOWERING *VIS-A-VIS* UPSURGE IN RODENT POPULATION

Bamboo is a potential resource of NEH Region. Among seven states of NEH, Mizoram occupies highest (38.0%) area under bamboo forest, followed by Meghalaya (26.8%). *Melocana bacifera* is the most common species of bamboo in almost all the states.

The predominant rodent species associated with bamboo flowering in Manipur and Assam are the white bellied rat, *Rattus rattus bullocki*, Manipur rat, *Rattus manipulus, B.bengalensis* and *B.indica.*

The minor rodent pests were *R.r.brunneusculus, R.r.tistae, R.bowersi, V.oleracea, H.humei, M.f.coolie, D.crumpi, C.b.badius* and *R.pruinosis* (Datta and Bora, 2003). Earlier *R.rattus* was reported to be the predominant species followed by *R.nitidus* and *B.bengalensis* during the 1991-94 bamboo flowering (Bhattacharjee *et al.*, 1998).

Mizoram has been suffering from historical, periodic cycles of famines, Mautam (flowering of *Melocanna baccifera*) and Thingtam (flowering of *Dendrocalamus longispathes* and *Bambusa tulda*). The Mautam is reported to occur thirty years after Thingtam and Thingtam occure eighteen year after Mautam. The effects of the two famines are however, different in magnitude. Mautam is considered to be more devastating than Thingtam. Based on the previous records and relevant facts it is predicted that the mass flowering of bamboo will occur in an estimated area of 18,000 square kilometres in the states of Mizoram, Tripura, Manipur and parts of Assam and Meghalaya during 2005-2007. The epicentre of bamboo flowering will be in Mizoram. As precautionary measures for combating the impending Mautam, monitoring of bamboo flowering and accompanying rodent population increase, several measures like purchase of rat tail to encourage public participation in rodent control program, free supply of locally fabricated traps, use of safer rodenticides, creating public awareness and motivation for community rodent control have been taken up. AINP on Rodent control (ICAR) and Directorate of Plant Protection Quarantine and storage (Govt. of India) is keeping a close vigil on the situation of mass flowering of bamboo *viz-a-vis* rodent population buildup in collaboration with concerned States.

CONCLUSIONS

The NEH centre of All India Co-ordinate Research Project on Rodent Control was established in 1982 at the ICAR Reserch complex for the NEH region at Barapani, Meghalaya. Considerable data has ben generated on density and species composition of rodents in the different agro-limatic zones of the area. Although estimate of damage to different crops is no exhaustive, the data on distribution of rodent species is well documented. The pecautionary and preventive measures to combat/lessen the impact of 2005-2007 bamboo flowering and accompanying famine have been initiated.

IX. PUNJAB

The state of Punjab is situated between the latitude of 29° to 32° North and longitude of 72° to 76° East. With 70% of the population involved in farming, agriculture contributes around 43% to the total revenue of the state. The state in turn contributes about 55% of the surplus food grains to the national food stock.

SOILS

The soils of Punjab have developed on the alluvium deposited by the Satlej and Beas rivers. They are of three major categories namely aridic, ustic and udic types. Irrigation is extensive with about 85% of the net cropped area under irrigation, the largest proportion of 97% in Amritsar district and the least of 39% in Hoshiarpur.

CLIMATE

Climate has wide variations with very cool winters and extremely hot summers. The rainfall varies from 300mm in the south western parts to 1400 mm in northern and north eastern parts. Of the two growing seasons kharif extends from June to November and rabi spreads from October to April.

LAND USE AND MAJOR CROPS

Out of the total geographical area, 83.2% is net sown area, 4.4% is under forest cover and the remaining is fallow and waste land. The major two crop systems are: Rice-wheat, Cotton-wheat, Maize-wheat, Groundnut-wheat, Arhar-wheat, Bajra-wheat and Rice-lentil. The major three crop systems are: Maize-potato-wheat, Rice-potato-wheat, Rice-rape seed-mustard, Rice-rape seed-mustard, rice-wheat-moong) and Maize-chari-berseem.

Wheat is the major rabi crop. Other crops grown in rabi are barley, gram, rape seed and mustard. Rice is the most cultivated crop during kharif followed by maize, cotton, sugarcane, groundnut and pearl millet. Potato is cultivated in large areas. Cauliflower, tomato, chillies, brinjal, okra, cucurbits, leguminous and root vegetables are also grown. Citrus is the largest cultivated fruit. The other fruits raised are peach, guava, ber and grapes.

AGROCLIMATIC ZONES (Table 1, Fig. 1)

Based on physiography, climate, rainfall, water resources and soil characteristics, Punjab is divided into five agro-climatic zones (Table 1 & Fig. 1) namely, Zone I-Sub montane undulating zone, Zone II - Undulating plain zone, Zone III- Central plain zone, Zone IV- Western plain zone and Zone V- Western zone.

Fig. 1. Agro climatic zones f Punjab

1. SUB MONTANE UNDULATING ZONE: Tts zone extends along the eastern border of the state with just 10 to 20 km in ridth in most of the region except in Gurudaspur district where it is much wier. The zone consists of part of Gurudaspur, Hoshiarpur, Ropar and Patiala districts. Soil is medium to heavy textured as well as light to medium texturd. Rainfall received is 50-300mm. During kharif maize and paddy are the major rops while groundnut and sugarcane are grown considerably. Wheat is the chief cop during rabi. Mango is grown over a large area. Guava in Ropar and litchi in Pathankot are the other fruits cultivated.

2. UNDULATING PLAIN ZONE : This zone conists of western parts of Gurudaspur and Hoshiarpur districts, parts of Jallandhar, opar, Ludhiana and Patiala districts. Rainfall ranges 800-900mm. The northern pars of the zone have medium to heavy textured soil while southern parts have ligt to medium textured soil. During kharif, paddy is the major crop followed by naize. Sugarcane cultivation is also considerable. Wheat is the principal crop in rai. Oilseeds are also important crops in several areas. Amongst fruits, mango occpies largest area. Litchi, citrus and guava are grown in certain pockets.

3. CENTRAL PLAIN ZONE : It comprises alrost the whole of Amritsar district, flood plains of Rabi and Beas rivers, western parts of Gurudaspur district, entire district of Kapurthala, most of Jallandhar and udhiana districts, parts of Ferozepur,

Table 1 : Agroclimatic zones and major crops of Punjab

ZONE	Districts & taluks	Soil type	Rain fall (range)	Cropping system	Major rodent species
SUB-MONTANE UNDULATING ZONE	Parts of Gurudaspur, Hoshiarpur, Ropar, Patiala Dts.	Medium to heavy textured, Light to medium textured.	50-300mm	Maize and Paddy based. Wheat, sugar cane, ground nut, guava, litchi.	*Bb, Mm, Mus,Ge*
UNDULATING PLAIN ZONE	Parts of Gurudaspur, Hoshiarpur, Jallundar, Ropar, Ludhiana and Patiala Dts.	Medium to heavy textured, Light to medium textured	800-900mm	Paddy, Maize & Sugar cane based (*Kharif*) Wheat (*rabi*), oilseeds, mango, litchi, citrus, guava.	*Bb, Mm, Ti, Mus,Ge*
CENTRAL PLAIN ZONE	Most of Amritsar Dt., flood plains of river Ravi and Beas, Parts of Gurudaspur Dt., most parts of Kapurthala, Jallundar and Ludhiana, parts of Ferozepur, Sangrur, and Patiala Dts.	Medium to heavy textured, Light to Medium textured	50-500mm	Paddy and Wheat based. Maize, groundnut, cotton, sugar cane, gram, barley, pear, guava.	*Mm, Bb, Ti, Mus*
WESTERN PLAIN ZONE	Parts of Firozepur, Amritsar & Faridkot Dts., parts of Sangrur & Bhatinda Dts.	Medium to heavy, Medium with mild to serious alkali problem soils.	400-500mm	Cotton based, Paddy –Pulses, Bajra-Pulses, cotton, moong, maize, sugar cane, oil seeds, gram, pear, guava	*Mm, Bb, Ti*
WESTERN ZONE	Parts of Bhatinda, Faridkot and Ferozepur Dts.	Sandy to Sandy loam, Alluvial deposits, highly calcareous and rich in lime.	200-500mm	Cotton-gram-wheat *moong*, wheat, barley, bajra, cotton, rice, maize, pulses & oil seeds. Bajra-Paddy.	*Ti, Mm, Mus, Ge*

Sangrur and Patiala districts. The temperature varies from 4°C in January to 41°C in summer. Rainfall varies a lot ranging 50 to 500 mm. Soil is medium to heavy textured, and light to medium textured. Paddy is the principal crop during kharif. Other kharif crops are maize, groundnut, cotton and sugarcane. During rabi, wheat is the major crop. Gram and barley are also raised. Pear and guava are major fruit crops followed by grapes.

4. WESTERN PLAIN ZONE: Parts of Firozepur, Amritsar, Faridkot, Sangrur and Bhatinda districts form this zone. The soils are medium to heavy, medium with mild to serious alkali problem. Annual rainfall varies 400-500mm. During kharif, paddy, American cotton, moong and maize are grown extensively. To some extent

bajra and sugarcane are also cultivated. Wheat is the principal crop during rabi, oil seeds, gram and barley are other important crops of rabi.

5. WESTERN ZONE : The zone comprises parts of Bhatinda, Faridkot and Ferozepur districts. Soils are sandy to sandy loam, are alluvial deposits, highly calcareous and rich in lime. The annual rainfall varies from 200-500 mm. Pulses and oil seeds are grown extensively during kharif. Wheat is the major rabi crop followed by barley, bajra, American cotton, rice and maize.

PEST STATUS AND DISTRIBUTION OF RODENTS

The crop fields had a more diverse species composition comprising of *N.indica, G.ellioti, M.platythrix, M.booduga* and *M.musculus*. *M.hurrianae* was found in crop fields and wasteland. Commensal species *R.rattus* and *M.musculus* inhabited residential premises, godowns, warehouses, stores and poultry farms. Orchards were predominantly infested by the squirrel, *F.pennanti*.

(a) Wheat (Tables 3 & 4): The crop was mainly infested by *B.bengalensis, T.indica and M.meltada* in the undulating plain zone which caused 3.9-5.2% loss in 1989 and 3.9-12% in 1991.

(b) Paddy (Tables 3 & 4): The damage was quite high at 1.1 to 17.5%. In undulating plain zone, the crop was damaged by *B.bengalensis, M.meltada, T.indica and Mus* but in western plain only *B.bengalensis* occurred.

(c) Millet (Table 4): *T.indica* and *Mus* were the major pests in western plain zone.

(d) Sugarcane : The losses ranged form 2.1 to 21.6% caused by *B.bengalensis, T.indica, R.meltada* and *Mus* (Table 3). *G.ellioti* also occurred (Table 4).

(e) Maize (Tables 3 & 4) : Damage to maize was 10.7%. *B.bengalensis* and *M.meltada* infested maize fields in undulating plain zone. When maize was grown along with bajra and chari, the species damaging were *B.bengalensis, T.indica, Mus, M.booduga* in undulating plain zone and only *B.bengalensis* in central plain zone (Table 4).

(f) Bajra + paddy + sugarcane : This cropping system had infestation of *B.bengalensis, T.indica* and *Mus* in undulating plain zone and *B.bengalensis, M.meltada, T.indica* and *Mus* in central plain zone.

Table 2 : Species composition of rodents in different habitats of Punjab (1978-84)

Habitat	Rodent species reported
Crop fields, Grassland	*B.bengalensis* *R.meltada* *T.indica*
Crop fields	*N.indica, G.elioti, M.platythrix, M.booduga, M.musculus*
Crop fields & waste lands	*M.hurriane*
Residential premises, Godowns, Warehouses, Stores, Poultry farms.	*R.rattus, M.musculus*
Orchards	*F.pennanti*

Table 3 : Rodent species infesting and damage caused to cultivated crops in Punjab (based on Parshad 1999)

Crop	Damage		Rodent pests	References
	Crop stage	% Dam. / YL (kg/ha.)		
Wheat	Pre harvest	3.9-5.2 YL 105-216	*Bb, Ti*	Malhi and Parshad' 1989
	Pre harvest	3.9-12.0	*Bb, Rm*	Parshad, 1991
Rice	Preharvest Irrigated	1.1-17.5 YL 46-528	*Bb, Rm*	Anon, 1991
Sugarcane	Partially damaged canes	2.1-21.6	*Bb, Ti, Rm, Mus*	Ahmad and Parshad, 1985
	Dried canes	3.2		
	Total YL	3833		
Maize	Seedling stage	10.7		Anon 1995
Groundnut	Plants & pods	3.9-19.0	*Ti, Rm, Mus, Mb*	Parshad *et al.*, 1987

Table 4 : Zone wise distribution of rodent species in Punjab (1986-2002)*

CROP	ZONES SUB MONTANE UNDULATING	UNDULATING PLAIN	CENTRAL PLAIN	WESTERN PLAIN	WESTERN
Wheat	-	*Bb, Mm, Ti*	-	-	-
Wheat+Maize	-	*Bb, Ti, Ge*	*Ti, Mus, Bb, Ge*	-	-
Paddy	-	*Bb, Mm, Ti, Mus*	-	*Bb*	-
Millet	-	-	-	*Ti, Mus*	-
Maize	-	*Bb, Mm*	-	-	-
Bajra+Maize+Chari	-	*Bb, Ti, Mus, Mb*	*Bb*	-	-
Bajra+Paddy+Sugarcane	-	*Bb, Ti, Mus*	*Bb, Ti, Mus, Mm*	-	
Sugarcane		*Bb, Rm, Ti, Mus, Ge*		*Bb, Mm, Ti, Mus*	-
Sorghum	-	-	-	-	*Ge, Mus sp*
Groundnut	-	*Bb, Ti, Mus, Ge*	-	-	*Mus sp., Ti*
Cotton	-	-	*Mm, Bb, Mus, Ti*	-	*Ti*
Fodder	-	-	*Bb, Ti, Mus, Mm*	-	-
Barren land	*Ti, Mus*	*Ti, Bb, Mm*	-	-	*Ti, Mus, Mm*
Forest area	*Ti, Mm, Mus*	-	-	-	-
Residential area, godowns, poultry etc	←	*Rr>Bb>Mms*			→

* Based on Annual Progress Reports of AICRP on Rodent Control, Punjab Agricultural University, Ludhiana.

(g) Groundnut: Damage was severe at 3.9-19% (Table 3). *B.bengalensis, T.indica, Mus* and *G.ellioti* infested groundnut in undulating plain and *B.bengalensis, M.meltada, T.indica* and *Mus* in western zone.

(h) Cotton : The cotton fields had *M.meltada, B.bengalensis, Mus* and *T.indica* in central plain zone.

(i) Fodder : The fields were infested by *B.bengalensis, T.indica, Mus sp* and *M.meltada* in central plain zone.

(j) Bajra : This crop was infested by *B.bengalensis* and *G.ellioti*, whereas bajra-maize fields harboured only *B.bengalensis.*

(k) Oats : It was infested by *B.bengalensis* only.

(l) Sorghum : This crop infested by *G.ellioti* and *Mus sp.* in western zone.

(m) Musk melon : It was infested by *B.bengalensis, M.meltada* and *Mus.*

(n) Barren land : The barren lands had *T.indica, M.meltada* and *Mus* in submontane undulating zone, *T.indica. B.bengalensis* and *M.meltada* infested undulating plain zone while *T.indica, Mus* infested western zone (Table 4).

(o) Forests : The forest areas had only *T.indica* and *Mus* in sub montane undulating plain zones (Table 4).

(p) Residential premises, godowns, stores and poultry : These indoor habitats had the two ubiquitous commensals, *R.rattus* and *M.musculus* in addition to the emerging commensal, *B.bengalensis* in all the zones (Table 4).

Table 5 : The pattern of species abundance of rodents since 1979 in Punjab

	Crops	Rodent species composition (M/m/s)*								
		Bb	*Ni*	*Mp*	*Mb*	*Mms*	*Ti*	*Mm*	*Fpm*	*Gi*
1979-1983	Wheat, sugarcane, grass land, waste land.	M	m	s	m	m	m	M	m	s
1984-1988**	Wheat, sugarcane, groundnut, cotton, millet, sorghum, garden nursery, guinea grass, barren fields, forest area.	M	-	-	m	m	m	M	m	s
1989-1993	Paddy, sugarcane, wheat, cotton, groundnut, maize, millet, black gram, Musk melon, waste land	M	-	-	m	m	m	m	m	s
1994-1998	Paddy, wheat, sugarcane, Bajra, sorghum	M	-	-	m	m	M	s	m	s
1999-2004	Paddy, wheat, sugarcane, maize, moong, millet, bajra, oat, berseem, vegetables	M	-	-	m	m	M	s	m	s

- Not trapped. * Other species not found except *Rr* which is a commensal rat. **Floods in 1988. M – Major; m – minor; s – sporadic

Table 6 : Major pests and diseases of major and minor crops of Punjab

Crop Major crops	Major insect pests	Major diseases	Major rodent species
Rice	Plant hoppers, leaf folder, grass hoppers, rice hispa, rice root weevil, rice stem borer, Gundhi bug, rice ear-cutting caterpillar.	Bacterial leaf blight, bacterial leaf streak, blast, brown leaf spot, sheath blight, sheath rot stem rot, false smut, bunt	*Bi, Rm, Mus, Ti*
Wheat	Sucking insect pests like aphid, jassid and brown mite, army worm, gram pod borer.	Wheat rust, loose smut, flag smut or leaf smut, ear cockle and yellow ear rot, root rot, leaf blight, kernel bunt, powdery mildew.	*Bb, Ti, Mus*
Sugarcane	Pyrilla, White fly, Black bug, Sugarcane mite, Sugarcane thrips, Termite, early shoot borer, top borer, stalk borer, Gurudaspur borer.	Red rot. Smut, Ratoon stunting disease, grassy shoot disease, red stripe, top rot, stinking rot, leaf scald	*Bb, Ti, Mm, Mms*
Minor crops			
Maize	Maize borer, jassid and thrips, pyrilla, grey weevil, leaf feeding insects, army worm, silk cutter, hairy caterpillar, mite.	Seed rot and seedling blight, Philippine downy mildew, brown stripe, downy mildew, bacterial stalk rot	*Bb, Mm, Mus (Birds)*
Cotton	Bollworms, sucking pests	Leaf curl, root rot, bacterial blight, Anthracrose, leaf blight, leaf spots, grey mildew	*Mm, Ti, Mus*
Moong And Mash	Thrips, hairy caterpillar, semi looper, mite	Yellow mosaic virus, cercospora leaf spot, root rot, Anthracnose, Bacterial leaf spot.	NA*
Soybean	Hairy caterpillar, flea-beetle, white fly	Yellow mosaic	NA*
Groundnut	Aphid, white grub, hairy caterpillar	Cotton rot and seed rot, cercospora leaf spot, root knot	*Ti, Rm, Bb, Mms, Mb*
Gram	Gram caterpillar	Blight, grey mould, wilt, stem rot, foot rot	NA*
Field Pea	Pea stem fly, pea thrips, pea leaf minor, pea aphid, pea borer	Powdery mildew, wilt, rust	NA*
Berseem	Bihar hairy caterpillar, surface grass hopper, gram caterpillar, cabbage semi looper.	Stem rot	Rats & mice
Bajra	Root bug, grass hopper, grey weevil, pyrilla, fulgarid.	Green ear or downy mildew, grain smut, Ergot	*Bb, Ge*

NA*-Not available

CHANGES IN SPECIES COMPOSITION OVER THE PAST TWENTY FIVE YEARS (1979-2004) (Table 5)

B.bengalensis remained the most predominant species during the past twenty five years. During 1979-1988, *M.meltada* wasthe other major species, but from 1994-2004 *T.indica* emerged as the second mjor species. Two species namely, *N.indica* which was a minor species and *M.platythrix* which was a sporadic pest during 1979-1983 have become rare in the follwing years. The two *Mus* species, *M.booduga* and *M.musculus* and the squirrel, *F.pennanti* remained minor pests throughout this period. *M.meltada* surprisinglybecame a sporadic pest from its status as a major pest in 1979. The status f *G.ellioti* as a sporadic species remained unchanged from 1979 to 2004. The ropping pattern has changed from wheat based in 1979-1988 to paddy and whet based from 1989 onwards. This change seems to have affected *M.meltada* whose status as a major pest disappeared.

PREDOMINANT RODENT PESTS OF MAJOR CROPS IN PUNJAB

The pest and disease profile of major crps of Punjab including rodents is given in Table 6. The rodent pests complex comprises of four to five species namely, *B.bengalensis, M.meltada, T.indica* and *Mus* species. This typical species complex was seen infesting rice and groundnut. Wheat fields were colonized by *B.bengalensis, T.indica* and *Mus* species. *B.begalensis, T.indica, M.meltada* and *M.musculus* were present in sugarcane. Maize fields had *B.bengalensis, M.meltada* and *Mus* species while *M.meltada, T.indica* and *Mus* species were seen in cotton.

CONCLUSIONS

Punjab Agricultural University, Ludhian has been the Centre of Rodent Research since early seventies and was one ofthe first three centers of 'All India Co-ordinated Research Project on Rodent Control since its inception. The data on species composition of rodents affecting the various crops of the state is voluminous. The most predominant rodent speies to affect agriculture in Punjab is *B.bengalensis*. The two other pests of significance are *T.indica* and *M.meltada*. Surprisingly two species of *Mus, M.booduga* and *M.musculus* are found in several crops consistently. The distribution of *F.pennati* is restricted to fruit orchards while *N.indica* and *G.ellioti* are sporadic pests of insignificant value.

X. RAJASTHAN

Rajasthan is situated in the northwestern part of the Indian union (23°30' and 30°11' N latitude and 69°29' and 78°17'E longitude). The Aravalli hill ranges running from northeast to southwest bisects the state approximately into the western arid and eastern semi-arid or sub-humid regions. Arid zone occupies nearly 3, 17,090 sq. km area of which 2, 46,790 sq. km is hot arid and rest is classified as cold arid region. About 62% of the hot arid area falls in Rajasthan state only. The ecosystem is hyper-thermic and is characterized by low and erratic rainfall, poor soil health and frequent droughts. Physiographically the state can be divided into four regions: (1) The Western desert (Thar), (2) The Aravalli hill region, (3) The Eastern plains and (4) The South Eastern plateau region.

Soils of Rajasthan belong to five major types viz. 1. Aridisols, Alfisols, Entisols, Inceptisols and Vertisols. The arid region of the state is characterized by aridsols and is distributed in Churu, Sikar, Jhunjhunu, Nagaur, Barmer, SriGanganagar, Bikaner, Jaisalmer, Sirohi, Jodhpur, Pali and Jalore districts.

CLIMATE

The climate of western desertic part is characterized by low and erratic rainfall coupled with frequent spells of drought, extremes of diurnal and annual temperatures, low humidity and high wind velocity. The annual rainfall in state ranges from less than 100mm to 200-300 mm and varies significantly making this part most arid. The south-west monsoon lasts from June till mid September. Summer starts in March with temperature rising progressively through April, May and June. In western part mainly at Bikaner, Phalodi, Jaisalmer and Barmer maximum daily temperature varies between 40°C to 45°C, occasionally reaching 49° C during summer months. In winter the minimum temperature may fall to 2°C. A sharp decline in temperature during night is experienced throughout the western Rajasthan.

CROPPING PATTERNS

Agriculture in western Rajasthan is mainly dependent on rainfall thus mainly rain fed cropping in praitised in the region. The major crops grown during kharif are - pearl millet, green gram, moth bean, cluster bean, sesame, cucurbits etc. In rabi season wheat, barley, cumin, chickpea etc. are cultivated in limited areas depending upon the availability of irrigation facility. With the advent of canal irrigation through Gang canal, Indira Gandhi Canal, Jawai Canal etc. and increased exploration of ground water resources, the area under irrigated crops like groundnut, pigeon pea, castor, cotton, sugarcane, wheat, chickpea, cumin, isabgol, mustard etc. is on increase. In intensively irrigated regions of Sri Ganaganagar district, even rice cultivation is practised. The most predominant cropping patterns of the

region are: (i) Pearl millet-green gram-moth bea-sesame-cluster bean (as rain fed) and cotton & groundnut (irrigated) in kharif seson and (ii) wheat-mustard-cumin-chickpea, (irrigated) in rabi season. Among vegcable crops, solanacious vegetables (tomato, brinjal and chillies) and cucurbits are most commonly grown in the region. Jujube is the most important fruit crop. Howver, in recent years under limited irrigation farmers have started growing pomeranate, kinnow, amla, date palm etc.

Agro-economy of the arid region is main/ livestock based farming system. Thus a vast stretch of land, especially in Jaisamer, Barmer, Jodhpur and Bikaner districts are under perennial forage grasses or pchar lands. Major grass species in the region are *Cenchrus ciliaris, C.setigerus* ad *Lasiurus sindicus*. Besides these grasses, foliage of several native bushes an trees (*Ziziphus nummalaria* and *Prosopis cineraria*) are also used as good soure of animal feed.

AGRO CLIMATIC ZONES (Fig. 1; Table 1)

On the basis of rainfall pattern and cropfeatures Rajasthan state has been divided into nine agro climatic zones (Table 1; ig. 1). Of these, arid region covers four zones (IA, IB, IIA and IIB). Details of the agp climatic zones are summarized as under.

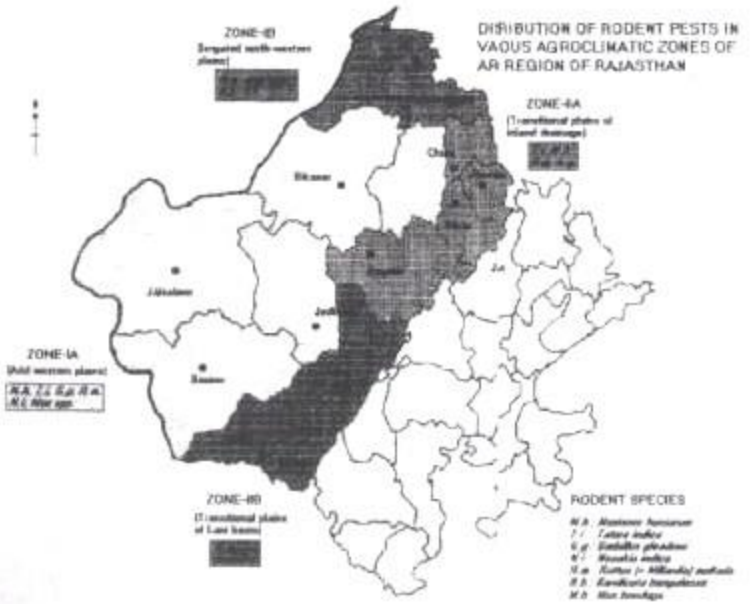


Fig .1 Distribution of rodent pests in various Agrocliiatic zones of arid region of Rajasthan

Table 1 : Details of agroclimatic zones and crop conditions in Rajasthan

Zone	Districts & tehsils	Soil type	Rainfall	Cropping patterns	Rodent species infesting
Zone 1-A: Arid Western Plain Zone. (36% Of State's Area), Rain Fed	All the *tehsils* of Jaisalmer, Barmer and Bikaner districts. Jodhpur, Phalodi, Shergarh and Osian *tehsils* of Jodhpur Dt. Sujangarh, Ratangarh and Sardarshahar *tehsils* of Churu Dt.	Calcareous, Desert soils, Sand dunes	100-350mm. Jul-Sept	Bajra – Moth Bajra-Green gram Gaur-Sesame	*Mh, Ti, Gg, Rm, Ge, Ni, Mus spp.*
ZONE 1-B, IRRIGATED NORTH-WESTERN PLAIN (Canal Irrigated)	Districts of SriGanganagar and Hanuman garh.	Alluvial, Sarozem, Asolian, Dunes, Food plain, Desert plain, Gravely and Laterite	253mm	Bajra, moth, guar, jowar, moong, gram, sesame, rape & mustard, cumin.	*Rm, Mms, Mh, Ni, Ti, Rr, Bb, Gg*
ZONE II-A: TRANSITIONAL PLAIN ZONE OF INLAND DRAINAGE	Nagaur, Sikar, Jhunjhunu districts. Taranagar, Churu & Rajgarh *tehsils* of Churu district.	Sandy loamy, Clay loamy	374-560mm. mid June to Sept	Pearl millet, pulses, gram, sorghum, sesame, wheat, rape & mustard, ber, anar	*Mh, Ti, Rm, Gg, Ni*
ZONE II-B: TRANSITIONAL PLAIN OF LUNI BASIN (Rain Fed and Irrigated)	Districts of Jalore, Pali & Bilara. Bhopalgarh *tehsil* of Jodhpur Dt. Reodhar, Sheoganj of Sirohi district.	Red desert soil, Saline soil, Lithosols	330-500mm	Pearl millet, sorghum, maize, wheat, paddy, barley, pulses, chick pea	*Ti, Mh, Rm, Rc, Ti, Bb, Mus sp., Mb*
ZONE III – A: SEMIARID EASTERN PLAIN ZONE. (Rain Fed and Comparatively More Irrigated)	Districts of Jaipur, Ajmer and Tonk	Alluvial, Alfisols	450-612mm	Wheat, barley, maize, moth bean, pulses, sorghum, groundnut, gram, mustard, cotton, vegetables	*Ti, Rm, Mh, Bb, Mus sp.*
ZONE III-B: FLOOD PRONE EASTERN PLAIN ZONE. (Rain Fed and Comparatively More Irrigated)	Districts of Alwar, Bharatpur & Dholpur. Districts of Sawai Madhopur except the *tehsils* of Khandar and Sawai Madhopur.	Alluvial, Recent alluvium, calcareous		Pearl millet, sorghum, groundnut, rape & mustard, wheat, gram, barley, pigeon pea.	*Ti, Rm, Bb, Mus sp.*

Zone	Districts & tehsils	Soil type	Rainfall	Cropping patterns	Rodent species infesting
ZONE IV-A: SUB-HUMID SOUTHERN PLAIN AND ARAVALLI HILL RANGE (Rain Fed & 32% Irrigated)	Aravalli hills 35 *tehsils* of Udaipur, Bhilwara, Chittorgarh and Sirrohi districts	Lithosols of Alluvium	500-900mm	Pearl millet, sorghum, maize, wheat, barley, rice, pulses, sesame, rape & mustard, groundnut, cotton	NA*
ZONE IV-B: SOUTHERN HUMID PLAIN ZONE (21.5% Irrigated, Rest Rainfed)	Districts of Dungarpur and Banswara, South-eastern parts of Udaipur Dt. & Southern part of Chittorgarh Dt.	Red, Mixed Red, Black Medium Black, Medium textured Calcareous	700-1180mm	Maize, paddy, sorghum, wheat, black gram, pigeon pea, moong, gram, groundnut. sesame, linseed, cotton.	NA*
ZONE V: SOUTH EASTERN HUMID PLAIN ZONE	Districts of Bundi, Kota & Jhalawar. Sawai Madhopur and Khandor *tehsils* of Sawai Madhopur Dt.	Black loam	690-1000mm	Sorghum, wheat, gram. Sesame, linseed, sugar cane, soybean, vegetables, fruits.	NA*

NA*-Not available

1. ARID WESTERN PLAINS (Zone 1 A) : This one comprises of all the tehsils of Jaisalmer, Barmer and Bikaner districts; Jodhur, Phalodi, Shergarh and Osian tehsils of Jodhpur district and Sujangarh, Ratangarh and Sardar Sahar tehsils of Churu district. Desert soils and sand dunes ocupy the major area in the zone. These are wind blown, Aeolian soils, loamy fine to coarse sandy in texture. These may be calcareous at places. The mean daily temperatures at Jodhpur range from maximum of 40°C in June to a minimum of 8° in January. Rainfall ranges from 100mm in the west to about 350mm in the east. Cultivation is mainly practiced in rainy season on the slopes of low to medium sand dunes and sandy plains. The common crops grown are pearl millet, green gam, moth bean and cluster bean. Wherever ground water is available, rabi crops like wheat, barley mustard and cumin are also grown.

2. IRRIGATED NORTH-WESTERN PLAIN (Zone B): This zone covers the districts of SriGanganagar and Hanumangarh. Extremearidity marked with high summer and low winter temperature is the usual characeristic of this zone. The soils here are alluvial deposits of river Ghaggar, loam tosilty clay loam in texture and are calcareous in nature. At many places they are itermixed with sandy material. The rainfall ranges from about 100mm in the southwest to about 350mm in the east. The mean daily temperature range at SriGanagaagar ranges from 4.7°C to 20.5°C in January 28°C to 42.1°C in June. The region is rich in agriculture production due to a well developed irrigation network through canals like, Ganga and Indira Gandhi

Table 2 : Rodent species composition of Arid Agro-climatic zones of Rajasthan

Year (Period)	Major crops	Zone -IA ARID WESTERN PLAIN		Zone - IB IRRIGATED N. WESTERN PLAIN		Zone-II A TRANSITIONAL PLAINS OF INLAND DRAINAGE		Zone-II B TRANSITIONAL PLAIN OF LUNI BASIN	
		Crops	Species	Crops	Species	Crops	Species	Crops	Species
1979-1983	Kharif	Pearl millet, moong, moth, guar, sesame, cotton	***M.hurrianae, T.indica, G.gleadowii, R.meltada, G.nanus***	Maize, sorghum, rice, moong, groundnut, cotton, sugarcane	***R.meltada, M.musculus, M.hurrianae, N.indica***	Pearl millet, moong, moth, guar	***M.hurrianae T.indica R.meltada G.gleadowii***	Pearl millet, sorghum, moong, moth, sesame, guar	***T.indica, M.hurrianae, M.meltada, R.cutchicus***
	Rabi	Wheat, mustard, barley, gram, cumin	***M.hurrianae, T.indica, R.meltada***	Wheat, barley, gram, chick pea, mustard, pigeon pea	***R.meltada, T.indica, R.rattus, B.bengalensis***	Wheat, gram, mustard, barley, pigeon pea	***M.hurrianae, T.indica, R.meltada***	Wheat, gram, mustard, barley	***T.indica, M.hurrianae, R.meltada***
1984-88	Kharif	Pearl millet, moong, moth, guar, sesame, cotton	***M.hurrianae, T.indica, G.gleadowii, R.meltada, T.indica***	Maize, pearl millet, sorghum, groundnut, sugarcane, cotton	***R.meltada, M.musculus, G.gleadowii***	Pearl millet, moong, moth, guar	***T.indica, M.hurrianae, R.meltada, G.gleadowii***	Pearl millet, sorghum, moong, guar, sesame	***T.indica, M.hurrianae, R.meltada***
	Rabi	Wheat, mustard, barley, gram, isabgol	***M.hurrianae, T.indica, R.meltada***	Wheat, gram, mustard, barley, pigeon pea, gram	***T.indica, R.meltada, B.bengalensis, M.musculus***	Wheat, gram, mustard, barley, pigeon pea	***M.hurrianae, T.indica, R.meltada***	Wheat, gram, mustard, barley, castor	***T.indica, M.hurrianae, R.meltada***
1989-1993	Kharif	Pearl millet, moong, moth, guar, sugarcane	***M.hurrianae, T.indica, G.gleadowii, R.meltada***	Maize, pearl millet, rice, groundnut, cotton sugarcane	***M.hurrianae, R.meltada, M.musculus, T.indica, G.gleadowii***	Pearl millet, moong, guar	***T.indica, M.hurrianae, R.meltada, G.gleadowii, N.indica***	Pearl millet, sorghum, moong, guar, sesame	***T.indica, R.meltada, B.bengalensis***
	Rabi	Wheat, mustard, cumin, isabgol	***M.hurrianae, T.indica, R.meltada***	Wheat, gram, mustard	***R.meltada, T.indica, M.musculus, B.bengalensis, M.hurrianae***	Wheat, gram, mustard, barley, pigeon pea	***M.hurrianae, R.meltada, G.gleadowii, N.indica***	Wheat, gram, mustard, barley	***T.indica, R.meltada, B.bengalensis, Mus spp.***
1994-98	Kharif	Pearl millet, moong, moth, guar, chillies	***M.hurrianae, G.gleadowii, G.nanus, T.indica, R.meltada***	Maize, sorghum, rice, groundnut, cotton, sugarcane	***R.meltada, T.indica, Mus spp. B.bengalensis***	Pearl millet, moong, moth, guar	***T.indica, M.hurrianae, R.meltada, G.gleadowii, N.indica***	Pearl millet, sorghum, moong, guar, sesame	***T.indica, R.meltada, B.bengalensis, Mus spp.***
	Rabi	Wheat, mustard	***M.hurrianae, T.indica, R.meltada***	Wheat, gram, mustard	***R.meltada, Mus spp., T.indica***	Wheat, gram, mustard, barley, pigeon pea	***M.hurrianae, T.indica, R.meltada, N.indica***	Wheat, gram, mustard, barley	***T.indica, M.hurrianae, R.meltada, B.bengalensis***
1999-2003	Kharif	Pearl millet, moong, moth, guar, chillies	***M.hurrianae, G.nanus, T.indica, R.meltada, G.gleadowii, N.indica***			Pearl millet, moong, moth, guar	***T.indica, M.hurrianae, R.meltada, G.gleadowii, N.indica***	Pearl millet, sorghum, moong, guar, sesame	***R.meltada, T.indica, B.bengalensis, Mus spp.***
	Rabi	Wheat, mustard, cumin, isabgol	***M.hurrianae, T.indica, R.meltada, N.indica, Mus spp.***			Wheat, gram, mustard, barley	***M.hurrianae, T.indica, R.meltada, N.indica***	Wheat, gram, mustard, barley	***T.indica, R.meltada, M.booduga, B.bengalensis***

* Mostly rainfed crops

N.indica: Irrigated croplands in Bikaner and afforestation area in Chiru and Nagaur

Mild drought years: 1978, 1980, 1981; Moderate drought years: 1984, 1985; Severe drought years: 1986, 1987, 1991, 2002

canals. A variety of field crops viz., rice, cotton, groundnut and sugarcane (in kharif) and wheat, gram, mustard, vegetable etc. (rabi) are now grown in this zone.

3 TRANSITIONAL PLAIN OF INLAND DRAINAGE (Zone II A): This zone is spread over Nagaur, Sikar, Jhunjhunu districts and Tranagar, Churu and Rajgarh tehsils of Churu district. It is situated in the west ofAravallis, characterized by low and erratic precipitation, moving sand dunes, poor and impeded drainage and salinity and/or sodicity in soils. The soils are sandy loams to clay loams and cultivation is restricted due to shallow depth and stony surface. Red desert soils, saline and lithosols are found in depressions. The rainfall ranges from 300 mm in the west to about 500 mm in the east. The mean daily maximum temperature ranges from 22.0°C to 39.7°C and the mean daily minimum temperature ranges from 5.3°C to 27.5°C. Due to conditions of erratic precipitation, a large area is put under pearl millet and legumes like green gram, moth bean and cluster bean etc. in kharif. In addition, groundnut also occupies a sizeable area. In rabi irrigated wheat, gram and barley are important crops.

4. TRANSITIONAL PLAIN OF LUNI BASIN (Zone II B): This zone covers districts of Jalore, Pali and Bilara and Bhopalgarh tehsil of Jodhpur district. In Jodhpur, Jalore, Pali and Barmer districts red desert soils are found. Saline soils are found in Ranns of Barmer district. About 27 percent of the cropped area is under irrigation mainly from canals and wells. The rainfall ranges from 300mm in the west to 500mm in the east. The principal crops of the zone are pearl millet, kharif pulses, sesame, maize, wheat, barley, mustard and gram. The area is prone to floods by the river Luni with a 16 years flood cycle. The area under cotton is being expanded in the region with the increasing irrigation facilities.

THE RODENT FAUNA OF RAJASTHAN

The State is highly diverse and rich in rodent fauna and consists of *Hystrix indica, Funambulus pennanti, Tatera indica, Meriones hurrianae, Gerbillus nanus indus, Gerbillus gleadowi, Vandeleuria oleracea, Rattus rattus, R. cutchicus, R. meltada pallidior, R.gleadowi, Mus musculus, M.cervicolor, M.platythrix, M.booduga, Golunda ellioti, Nesokia indica* and *Bandicota bengalensis* (Tripathi *et al.*, 1992). Amongst these *M.hurrianae* and *T.indica* are the most abundant species followed by *R.m.palliodor, R.c.cutchicus* and *G.gleadowi*. Others occur in low numbers. In general following is the distribution of rodents habitatwise (Rana *et al.*, 1994):

Sandy habitat : *M.hurrianae* > *T.indica* > *G.gleadowi* > *R.m.pallidior*

Gravel habitat: *M.hurrianae* > *T.indica* > *M.p.sadhu*

Rocky habitat: *R.c.cutchicus* > *M.p.sadu* > *M.C.phillipsi* > *F.pennanti*

Ruderal habitat: *T.indica* > *R.m.palliodor* > *M.hurrianae* > *G.gleadowi*

PEST STATUS AND DISTRIBUTION OF RODENTS (Table 3; Plate 8)

By virtue of their species diversity, high numbers and successful adaptation to arid ecosystems, rodents constitute one of the largest mammalian groups in the Rajasthan desert. By their burrowing activity and depredation on sparse vegetation rodents pave way for increased desertification and deterioration of vegetation. To exploit the limited resources they indulge in gnawing, debarking, cutting and feeding on anything that is edible from the sown/germinating seeds to ripe grains and fruits in cultivated crop fields, grassland, orchards, forest nurseries, forests and plantations (Table 4).

(a) Field crops: Sown, germinating seeds are damaged by *F.pennanti, T.indica, M.hurrianae* and *G.gleadowi*. Bajra is damaged at milky stage, pre harvest and harvest stages, and the damage is upto 38%. The species inflicting damage were *T.indica, M.hurrianae* and *G.ellioti* (Rana *et al.*, 1994). *M.hurrianae, T.indica* and *G.gleadowi* caused 57-61% damage to moth (Rana and Tripathi, 1999). Mustard crop at seedling stage and the grown plant suffered 22.9 to 30% reduction in plant stand due to *T.indica* > *M.hurrianae* > *R.m.pallidior* and *G.gleadowi* (Rana *et al.*, 1994; Rana & Tripathi, 1999). Damage to vegetables in general ranged 4.1 to 19.9% and damage was 40% fruits/plant for chillies. Damage inflicting species were *T.indica, M.hurrianae* and *R.m.pallidior* (Rana *et al.*, 1994).

Table 3 : Rodent species infesting and rodent damage to crops of Rajasthan

Field crops	Horticulture	Forest plantations	Grassland & Fodder
1. Sown, germinating seeds → *Fp, Ti, Mh, Gg*[1]	1. (a) Pomogranate–29% loss → *Fp*[1] (b) Pomegranate – 6.1 to 11.3% dam→ Ti, Fp[2]	1. Debarking → Mh, Ti, Rm, *Ni*[1,3,5]	1. Consumption of grass seeds → *Mh*[1]
2. Bajra at milky stage → *Ti, Mh, Ge*[1] Harvested Bajra	2. (a) Ber → *Mh, Ti*[1] (b) Ber nursery – 8-80% damage → *Ti, Fp*[2]	2. Slicing – *Ni*[2]	2. Feeding on grasses[1]
3. Chillies – 40% fruits/plant → *Ti, Mh, Rmp*[1]	3. Date palm → *Ti*[2]	3. (a) 3-30% damage to germinating seeds in forest nurseries → *Fp*[4] (b) Damage to sprouting seeds → *Fp*[5]	3. 77.3 to 97.3 rodents/ha → Ti & *Mh*[2]
4. Mustard-22.9 to 43.5 plant stand reduction → *Ti, Mh, Rmp*[1]	4. Guava → *Fp*[6]	4. Bamboo root damaged → Ti[6]	
5. Vegetable crops – 4.1 to 19.9% damage[1] → *Ti, Mh, Rmp.*		5. Teak forests → *Pp*[6]	
6. Mustard seedling 22.9 to 30% in plant stand → *Mh, Ti, Gg, Rm*[2]			
7. Gram – 19.6, Pea – 18.75% → *Mh, Ti, Gg*[2] (reduction in plant stand)			
8. Moth – 57 to 61% → *Mh, Gg, Ti*[2]			
9. Bajra – 38% → *Mh, Ge, Ti*[3]			

(1) Rana *et al.*, 1994. (2) Rana & Tripathi, 1999. (3) Tripathi & Jain, 1990. (4) Paunicker & Ahmad, 2002. (5) Idris 2004. (6) Prakash & Singh 1998

Fp-Funambulus palmarum; Ti-Tatera indica; Mh-Meriones hurrianae; Gg-Gerbillus gleadowi; Rm-Rattus meltada; Ge-Gollunda ellioti; Rmp-Rattus meltada pallidior; Ni-Nesokia indica; Pp - Petacerista philippensis (flying squirrel)

Horticulture crops: Pomogranate is damaged ıy *F.pennanti* which causing 29% loss (Rana *et al.*, 1994). In a later study the damage was estimated as 6.1 to 11.3% inflicted by *T.indica* and *F.pennanti* (Rna and Tripathi, 1999). Damage to ber nursery ranged 8-80% and was inflicted b *T.indica* and *F.pennanti* (Rana and Tripathi, 1999). Date palm and guava were damaged by *T.indica* (Rana and Tripathi, 1999) and *F.pennanti* respectively (Prakash and Singh, 1998; Paunicker and Ahmed, 2002).

(b) Forest plantations: Young seedlings are damaged by the debarking and slicing activities of rodents. *Albizzia lebbek*, *A.tortilis*,*Prosoppis cineraria* and *Parkinsonia aculeata* are the tree species debarked. The secies causing this type of damage are *M.hurrianae*, *T.indica* and *R.meltada*. Scing activity is mostly limited to underground roots by the burrowing activityof *Nesokia indica* resulting in the death of trees. Roots of bamboo were reportedto be damaged by *T.indica* (Prakash & Singh, 1998). Of late damage to sown andgerminating seeds of forestry trees by *F.pennanti* has been observed (Paunicker ad Ahmed, 2002; Idris, 2004). The flying squirrel, *Petaurista philippensis* was fund in well protected, dense teak forests around Udaipur (Prakash and Singh, 1998).

(c) Grassland and Fodder: The seeds of grsses sown to improve the fodder quality are dug up and eaten up by *M.hurriaae*. The high density of rodents at 77.3 to 97.3/ha, mainly composed of *T.indica* and *M.hurrianae* results in heavy depredation of nutritive, highly palatable grsses and other edible plants. This foraging pressure by rodents has changed the structure of plant community in Rajasthan desert resulting in non-productive nd degeneration type of vegetation (Rana *et al.*, 1994; Rana and Tripathi, 1999).

Species invasion occurred consequent to hanged land use pattern in northern, north-wastern parts of Rajasthan which werethe beneficiaries of canal irrigation and subsequent increased crop cultivation (Fig 2). Prior to irrigation, the land was dry deciduous, scrub jungle with undulatingsand dunes. The climate, soil and vegetation were similar to arid region of wetern Rajasthan as seen today. The hitherto xeric rodent fauna was predominanly composed of *M. hurrianae*, *T. indica* and *R. meltada* and to a small extent by*Gerbillus nanus*. Earlier *M. musculus* and *F. pennanti* were completely absent in oen fields. The change of landscape from desert ecosystem to one of irrigated cro fields in SriGanganagar district in northern Rajasthan with the introduction of Gnga canal (1927-28), Bhakra canal (1951-52) and Indira Gandhi Canal (1956-57) changed the scenario of rodent species infesting this area. The major changs were the disappearance of xeric species, *Gerbillus* and *M. hurrianae* rather the migration to drier and sandy lands and their replacement by mesic forms namly *M. musculus* in sugarcane and cotton fields, *N. indica*, *R. meltada* and *B. begalensis* in irrigated crop fields and

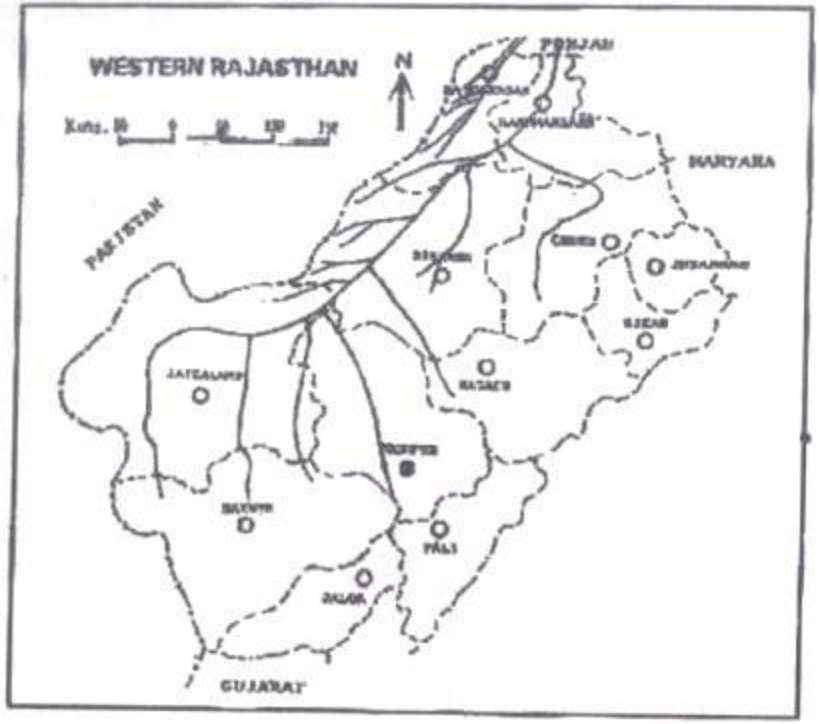


Fig. 2. Indira Gandhi Canal in Western Rajasthan

F .pennanti in fruit orchards. Only *T. indica* was successful in adapting to the changed cropping pattern. This invasion of changed landscape by more adaptable, successful, mesic species is likely to continue as more and more land comes under irrigation in Rajasthan resulting in decreased faunal diversity of rodents.

To sum up, in rain fed crops (pearl millet, green gram, moth, bean etc.) the gerbils, *M.hurrianae* and *T.indica* are the two most common rodent pest species. In addition to these gerbils, the crop fields located in inter dunal plains or near sand dunes also suffer due to infestation of another gerbil species, *Gerbillus gleadowi*. These field rodents start damaging the rain fed crops right from sowing and continue their destructive activities all through the cropping season and later in the threshing yards too. In the irrigated cropping systems (groundnut and cotton in kharif and wheat, mustard, cumin in rabi), *T.indica, Rattus (Millardia) meltada* and *M.hurrianae* are the major pests. Among *Mus* spp., *M.musculus* and *M.booduga* have been reported from irrigated fields. Five stripped squirrel, *Funambulus pennanti* may also be considered a minor rodent pest in crops where the fields have trees like, *Prosopis cineraria* and *Tecomella undulata*. However the squirrels are a major problem in arid horticulture. In Indira Gandhi Canal command

RODENT DAMAGE

Damage in moong

Damage in bajra

Damage in wheat

Damage in mustard

Damage in pomegranate

Damage in forestry plantation

areas of SriGanganagar and Bikaner Districts, the crop fields are mainly infested with *T.indica, R.meltada, M.booduga, B.bengalensis* and *N.indica*. Since rodents are omnivorous they may not show specific preference for any crop; however a complex of 3-4 rodent species are reported to have some association with cropping systems in arid ecosystem (Table 2).

CONCLUSIONS

The Rajasthan desert had the privilege of being extensively studied regarding its rodent fauna their eco-biology and impact on agriculture even before the establishment of co-ordinating cell of All India co-ordinated Research Project on Rodent Control. Since then enormous data has been generated on species infesting, extent of damage inflicted and technology to prevent such damages. Out of the nine Agroclimatic zones of the state, four covering the arid areas namely Arid Western Plains (Zone I A), Irrigated north-western plain (Zone I B), Transitional plain of Inland Drainage (Zone II A) and Transitional plain of Luni Basin (Zone II B) have been thoroughly investigated for species composition of rodents and damage inflicted.

OVERVIEW OF RODENT SPECIES DISTRIBUTION AND DAMAGE IN INDIA

The data generated on rodent damage to Indian agriculture and species involved are summarized in tables 1 to 3 and figures 1 and 2. Available data for states where AICRP on rodent control is not operating has also been included based on published work. The details of species composition of rodents and estimates of damage to major crops for different states is presented in three tables: information on species infesting major crops in Table 1, infestation on food crops in Table 2 and Figure 1, data on commercial, vegetable, fruit and plantation crops in Table 3 and Figure 2.

Summarily the rodent species distribution in major crops across the country is as follows:

Andhra Pradesh: Rice was infested by two species namely *B.bengalensis* and *M.booduga* while pulses were damaged only by *B.bengalensis. B.bengalensis, M.meltada* and *M.booduga* infested groundnut. *R.rattus* was the major pest of coconut.

Assam and Manipur: Data is available only for rice, *B.bengalensis, B.indica, M.booduga* and *R. sikkimensis* damaged the crop. Other species found in the state are *R.rattus, R.nitidus* and *D.lokriah*.

Bihar (Non AICRP reports): Rice was damaged by *B.bengalensis*.

Gujarat: *B.bengalensis, T.indica* and *M.meltada* were the three major rodent pests of Gujarat, infesting and damaging the major crops viz., wheat, rice, millets, maize, pulses and groundnut but their distribution pattern rather order of predominance varied from crop to crop. *R.rattus* was a pest of coconut. *M .hurrianae* was limited to western arid areas.

Haryana (Non AICRP reports): The major species reported are *B.bengalensis, M.meltada, T.indica* and *N.indica*.

Himachal Pradesh: The major rodent species damaging wheat, rice, maize and jowar were *B.bengalensis, M.musculus, M.booduga, R.meltada* and *R.rattus*. Fruits and vegetables were damaged by *B.bengalensis, M.musculus, R.rattus, M.booduga, G.ellioti, R.melatda* and *F.pennanti*.

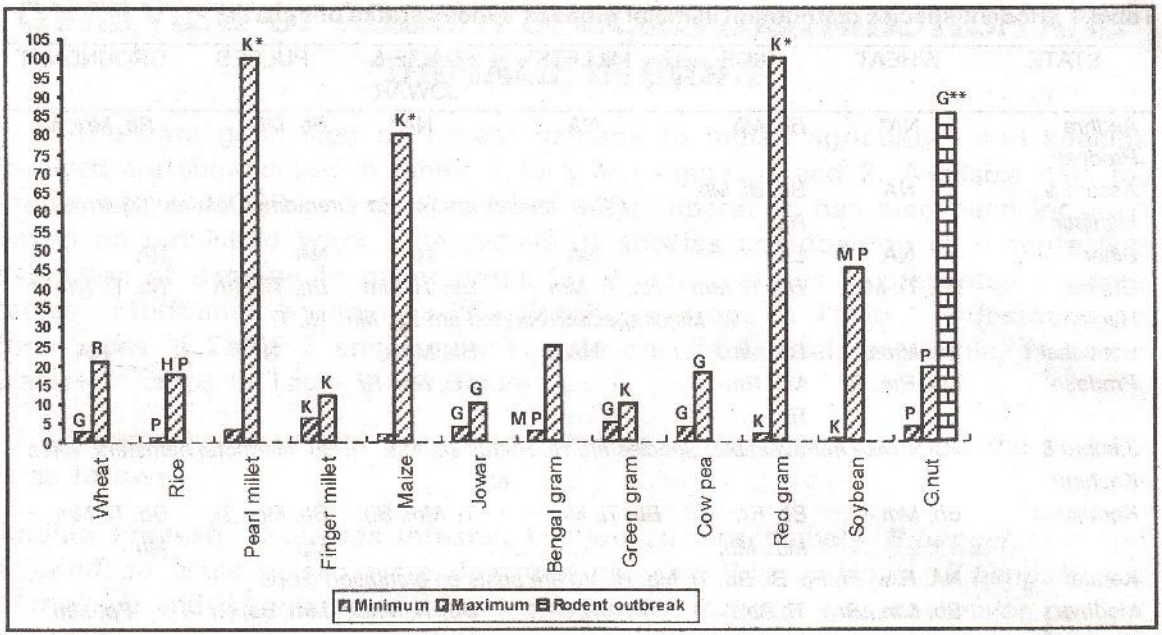
Jammu & Kashmir (Non AICRP reports): No information is available on cropwise distribution of rodents. But species reported were *H.indica, Rattus* sp. *M.meltada, T.indica, B.bengalensis,* marmots, hamsters, voles etc. (Table 4).

Table 1 : Rodent species distribution in major crops (various states of India

STATE	WHEAT	RICE	MILLETS	MAIZE & JOWAR	PULSES	GROUNDNUT
Andhra Pradesh	NA*	*Bb, Mb*	NA	NA	*Bb, Mb*	*Bb, Mm, Mb*
Assam & Manipur	NA	*Bb, Bi, Mb, Rs*	*Other spcies are Rr, Rn, Dremomys lokriah (Squirrels)*			
Bihar	NA	*Bb*	NA	NA	NA	NA
Gujarat	*Bb, Ti, Mm*	*Bb, Ti, Mm*	*Bb, Ti, Mm*	*Bb, Ti, Mm*	*Bb, Ti, Mm*	*Bb, Ti, Mm*
Haryana	*Major species reported are Bb, Mm, Ni, Ti*					
Himachal Pradesh[1]	*Bb, Mms, Mb, Rm, Rr*	*Bb, Mms, Mb, Rm, Rr*	NA	*Bb, Mms, Mb, Rm, Rr*	NA	NA
Jammu & Kashmir	*Cropwise not available. Species are Hi, Rattus sp. Mm, Ti, Bb. Marmots, hamsters, voles etc.*					
Karnataka[2]	*Bb, Mm*	*Bb, Rr, Mm, Mb,*	*Bb, Ti, Mm*	*Ti, Mm, Bb*	*Bb, Mm, Ti, Mp*	*Bb, Ti, Mm, Mb*
Kerala[3]	*NA. Rrw, Ft, Fp, Bi, Bb, Ti, Mb, Hi, Vo are ests on plantation crops.*					
Madhya Pradesh[4]	*Bb, Mm, Rr*	*Ti, Bb, Mm, Mb*	NA	*Bb, Ti, Mm, Mb*	*Mm, Bb, Rr*	*Fp, Mm*
Maharashtra	*Cropwise unavailable. Rr, Bb, Mb, fp, Ti, Ge, Hi & F.palmarum, Ft reported*					
NEH region	NA	*Bb, Rn, Mms, Rm*	NA	*Bb, Rr, Mb*	NA	*Bb, Rn*
Orissa	-	-	-	-	-	-
Punjab	*Bb, Ti, Rm, Ge, Mus*	*Bb, Rm, Ti, Ge, Mus*	*Bb, Ti, Mus*	*Bb, Mm, Mus*	*Bb, Mus, Mm*	*Ti, Rm, Bb, Mms, Mb*
Rajasthan	*Mh, Ti, Rm*	NA	*Ti, Mh, Ge*	NA	*Mh, Ti, Gg*	*Ti, Mm, Mh*
Sikkim	*Cropwise distribution not available. Bb andRattus ratoides, voles reported*					
Tamil Nadu	*Bb, Mb, Mm, Ti*	*Bb, Mm, Mb, Ti*	NA	NA	*Bb, Mm, Mb*	*Bb, Mm, Mb*
Tripura	*Crop wise distribution not available. Bb andRattus sp. reported*					
Uttar Pradesh	*Bb, Ti, Mm, Mb, Ni, Mp*	*Bb, Mp, Rr, Ni, Mb, Mc, Mm*				*Mp*
West Bengal		*Bb*	*Other spcies are Ti, Bi, Ni, Mm, Mb, Mp reported*			

1. APPLE, PEACH, PLUM, PECAN-*Bb, Rr, Mms, Mb, Ge.*
2. CARDAMOM - *Fpm, Bb; Coconut-Rrr, Rr; Cocoa - Ft, Rr.*
3. COCONUT-*Rrw, Ft, Fpm, Bi, Bb, Ti, Mb, Hi; Cocoa - Rr, FtFpm, Mb*
4. SOYBEAN - *Rr, Bb, Mm*

Bb-Bandicota bengalensis; Bi - Bandicota indica; Fp - Funambus palmarum; Fpn -Funambulus pennanti; Ft - Funambulus tristriatus; Ge - Gollunda ellioti; Gg - Gerbillus gadowii; Hi - Hystrix indica Mb-Mus booduga; Mc - Mus cervicolor; Mh -Mus hurrianae; Mm- Millardia meltéa; Mms-Mus musculus; Mp - Mus platythrix; Ni - Nesokia indica; Rm - Rattus meltada; Rn - Rattus nitidus; r - Rattus rattus; Rrw - Rattus rattus wroughtonii; Rs - Rattus sikkimensis; Ti - Tatera indica; NA-N: available



G - GUJARAT; R - RAJASTHAN; P - PUNJAB, HP - HIMACHAL PRADESH; K - KARNATAKA; NEH- NEH REGION; MP - MADHYA PRADESH; * Sown seeds; ** Rodent outbreak

Fig. 1. Rodent damage (%) to food crops in India

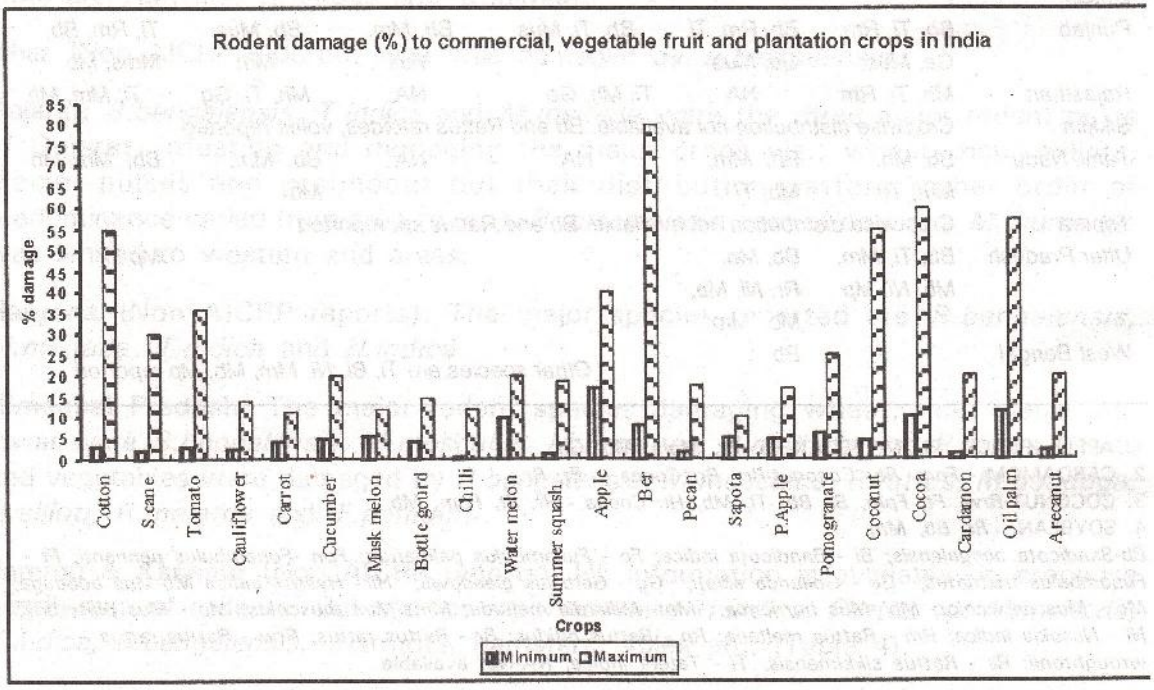


Fig.2.Rodent damage (%) to commercial, vegetable fruit and plantation crops in India

Table 2 : Rodent damage and species infesting food crops in India

Crop	Stage	Damage (%) YL (yield loss)	Species	State
WHEAT	Seedling to Maturity	5.9		Rajasthan[1]
(*Triticum*	Preharvest	18.7-21.3	*Mh, Ti, Rm*	Rajasthan[2]
aestivum)	-do-	6.3-8.2	*Bb, Rm*	H.Pradesh[3]
	-do-	3.9-5.2	*Bb, Ti*	Punjab[4]
		105-216kg/ha		
	Pre harvest	3.9-12.0	*Bb, Rm*	Punjab[5]
	-do-	100-200kg/ha	*Rm*	M.Pradesh[6]
	-do-	8.0-10.0	*Bb*	U.Pradesh[6]
	-do-	2.7-20.9	*Bb, Ti*	Gujarat[6]
	-do-	5.0-10.0	*Bb, Mm*	Karnataka[7]
		3.0-21.0	*Bb, Ti, Mm*	Gujarat[24]
		4.4-14.9	*Bb, Mms, Mb, Rm, Rr*	H.Pradesh[25]
RICE	Pre harvest	1.1-17.5	*Bb, Rm*	Punjab[8]
(*Oryza saliva*)		46-528kg/ha		
	-do-	98-213kg/ha	*Bb*	U.pradesh[6]
	-do-	1.3-6.7	*Bb, Rr*	M.Pradesh[9]
	-do-	10-12.5	*Rn, Bb*	Meghalaya[10]
	-do-	4.3	*Rn, Bb*	Mizoram[10]
	Grain formation	9-10	*Bb, Mm, Mb*	Karnataka[7]
	Milky stage	12-45kg/ha		
	Pre-harvest	45-90kg/ha	*Bb, Mb, Mm*	Karnataka[7]
	Post-harvest	15-50kg/ha		
	Hill regions	1-44.5	*Bb, Mb*	Karnataka[11]
	Hill region	62-79.7	*Bb*	Karnataka[12]
		72kg	*Bb,Mm, Mb, Rr*	Karnataka[13]
	Seedling	8.22	*Bb, Mb, Mp*	
	Harvest stage	17.56		A.Pradesh[14]
	Milky to maturity	4.6-16.8	*Bb, Rn, Mm*	NEH region[23]
		5.0-8.2	*Bb, Mm, Mb, Rm, Rr*	H.Pradesh[25]
		3.17% YL	*Bb, Bi, Mb, Rs***	Assam[26]
PEARL MILLET	Seedling	Almost 100% (Resown)	*Gg*	Rajasthan[15]
	Milky, Grain	Considerable	*Ti, Mh*	Rajasthan[15]
		3.0-12.0	*Bb, Ti, Mm*	Gujarat[24]
FINGER MILLET, (*Eleusine coracana*)	Milky, Grain	6.0-12.0	*Bb, Mm, Ti*	Karnataka[7]
MAIZE	Cobs	9.8	-	H.Pradesh[16]
(*Zea mays*)	Cobs	9.1	*Rn, Bb*	Meghalaya[10]
	Seedling	10.7	-	Punjab[17]
	Seedling	50-80	*Bb, Ti, Mm*	Karnataka[7]
	Cob formation	7.0	*Bb, Ti*	Karnataka[7]
	Harvest	12.5	*Ti, Bb, Rr, Mb*	Karnataka[7]
	Cobs	3.5-24.0	*Bb*	NEH regions[23]
		5.0	*Bb, Ti, Mm*	Gujarat[24]
		1.9-5.0	*Bb, Mm, Mb, Rm, Rr*	H.Pradesh[25]
JOWAR	Seedling	4.0-7.0	*Bb, Mm*	Karnataka[7]
(*Sorghum vulgare*)		4.0-10.0	*Bb, Ti, Mm*	Gujarat[24]

Crop	Stage	Damage (%) YL (yield loss)	Species	State
BENGAL GRAM	Pods	2.5	*Mm*	M.Pradesh[18]
(*Cicer arietinm*)	Plants & pods	11.0	*Bb*	A.Pradesh[6]
		3.0-25.0	*Bb, Ti, Mm*	Gujarat[24]
PIGEON PEA		3.0-7.0	*Bb, Ti, Mm*	Gujarat[24]
GREEN GRAM	Vegetative growth	10.0	*Bb, Mm, Ti*	Karnataka[7]
(*Phaseolus aureus*)		5.0-6.0	*Bb, Ti, Mm*	Gujarat[24]
COW PEA (*Vigna catiang*)		4.0-18.0	*Bb, Ti, Mm*	Gujarat[24]
RED GRAM	Seedling	50-100%	*Bb, Mm, Mp*	Karnataka[7]
(*Cajanus cajan*)	Pod formation	2.0	*Bb, Mm, Ti*	Karnataka[7]
SOYBEAN	Green pods	27.27	*Bb, Mm, Rr*	M.Pradesh[19]
(*Glycine max*)		44.76	*-do-*	M.Pradesh[20]
	Pod formation	0.6-3.0	*Mm, Ti*	Karnataka[7]
GROUNDNUT	Plants & Pods	3.9-19.0	*Ti, Rm,*	Punjab[21]
(*Arachis hypogea*)	Pod setting	4.5	*Bb, Mb, Mm*	Gujarat[22]
	Pod maturity	6.9	*Bb, Ti*	-do-
	Harvesting	7.3	*Mm*	-do-
	During rodent outbreak			-do-
	Seedling	2.9-85.4		-do-
	Peg formation	30-40	*Bb, Ti*	Karnataka[7]
	Mature pods	2%	*Bb, Mb*	-do-
	Hoarding	4.0-9.0	*Bb, Mm*	-do-
	Pods	3%	*Bb, Mb*	-do-
		0.26-10.1	*Bb, Rm*	NEH region[23]
		2.0-7.0		H.Pradesh[25]
SUNFLOWER (*Helianthus anus*)	Sown seeds	70	*Bb, Mm, Ti*	Karnataka[26]

** Mus mus musculus; ** Rattus sikkimensis*

(1) Singh & Saxena, '89 (2) Jain et al., 93a (3) Sheikher & Jain, 91a (4) Malhi & Parshad, '89 (5) Parshad, '91 (6) Rana et al., '94 (7) Sridhara, '99 (8) Anon, '91 (9) Patel et al., '92 (10) Singh et al., '94 (11) Chakravarthy et al., '92 (12) Prakash et al., '86 (13) Sridhara & Krishnamurthy, '79 (14) Rao & Singh, '83 (15) Tripathi et al., '92 (16) Kumar & Misra, '93 (17) Anon, '95 (18) Dubey et al., '92 (19) Khatri et al., '87 (20) Awasti & Agarwal, '91 (21) Parshad et al., '87 (22) Mittal et al., '91 (23) Pathak & Kumar, '01 (24) Butani & Vyas, '05 (25) Sharma '05 (26) Anon '04.

Karnataka: *B.bengalensis, M.meltada* were pests of wheat, *B.bengalensis, T.indica* and *M.meltada* infested millets, maize and jowar. *B.bengalensis, R.rattus, M.meltada* and *M.booduga* were pests of rice, *B.bengalensis, M.meltada, T.indica and Mus platythrix* damaged pulses and groundnut was infested by *B.bengalensis, T.indica M.meltada*, and *Mus booduga*. The plantation crops viz., cardamom, cocoa, rubber, coconut were damaged by *F.palmarum, F.tristriatus, R.rattus, R.r.wroughtonii* and *H.indica* (debarking).

Crops	Stage	Damage (%)/ YL (yield loss; kg/ha	Species	State
I. COMMERCIAL				
COTTON	Bolls	3.2-23.2	*Ti, Rm*	Gujarat[1]
(*Gossypium sp.*)	Damaged bolls	55-0	*Bb*	TamilNadu[2]
		4.0-6.0	*Bb, Ti, Mm*	Gujarat[40]
SUGARCANE	Partial damage			
(*Saccharum officinarum*)	to canes	2.1-21.6	*Bb, Ti, Rm, Mm*	Punjab[3]
	Dried canes	3.2	-	Punjab[4]
	Ratoon cane	15.0-30.0	-	U.Pradesh[5]
	Without lodging	6.8	*Ti, Bb*	U.Pradesh[6]
	With lodging	18.9	*Ti, Bb*	-do-
	Lodging of canes	YL: 520/1300		Karnataka[7]
		5.0-8.0	*Bb, Ti, Mm*	Gujarat[40]
MARIGOLD	Harvesting	4.0-5.0	*Bb*	Karnataka[42]
(*Tagetes erecta*)				
II.HORTICULTURAL CROPS				
(i) VEGETABLES				
TOMATO	Rind of fruits	11.1-37.3	*Bb*	Punjab[8]
(*Lycopersicum esculentum*)	Rind of fruits	19.0	*Ti, Mh, Rm*	Rajasthan[11]
	Mature fruits	13.5-16.5	*Bb, Ti*	Haryana[9]
	Mature fruits	2.6-35.6	*Bb, Rm*	Gujarat[10]
	Mature fruits	5.0	*Bb*	Karnataka[12]
		5.0	*Ti*	Gujarat[40]
		upto 10.0	*Bb*	Karnataka[20]
	Flowering	4.0	*Bb*	Karnataka[42]
	Fruiting (summer)	6.0	*Bb, Mp, Ti*	Karnataka[42]
	Harvest	5.0	*Bb*	Karnataka[42]
KNOL-KHOL	Bulb formation &	5.0-6.0	*Bb*	Karnataka[42]
(*Brassica oleracea var gongylodes*)	harvest stage	(summer)		
		2.0 kharif	*Bb, Ti*	Karnataka[42]
POTATO	Seedlings	5.0	*Bb, Mm, Ti*	Karnataka[20]
(*Solanum tuberosum*)	Flowering	4.0	*Bb*	-do-
	Fruiting	6.0	*Bb, Mp, Ti*	-do-
	Harvest	5.0	*Bb*	-do-
		3.5-9.0	*Bb*	Haryana[46]
PEA (*Pisum sativum*)	Seedling	1.1	*Bb, Rm*	Punjab[13]
	Pods	5.9	*Bb, Rm*	Punjab[13]
	Pods	1.8-5.6	*Bb, Rm*	H.Pradesh[1]
	Plant stand	18.7	*Mh, Ti*	Rajasthan[1]
		2.3-8.0	*Mm, Bb, Mb, Rm, Rr, Ge*	H.Pradesh[44]
CABBAGE (*Brassica oleracea var capitata*)		2.5-9.0	*Mm, Mb, Rr, Rm, Ge*	H.Pradesh[44]
	Head formation	5.5	*Bb*	Karnataka[42]

Crops	Stage	Damage (%)/ YL (yield loss; kg/ha)	Species	State
BRINJAL (*Solanum melongena*)	Harvesting	2.0-6.0	*Bb*	Karnataka[42]
CAULIFLOWER (*Brassica oleracia*)		2.3-12.7	*Mb, Bb, Mb Rm, Rr*	H.Pradesh[25]
		4.44-13.9	*Bb, Mm, Rm, Mb*	H.Pradesh[45]
		0-6	*Bb, Mm, Mb, Ti*	Karnataka[41]
CARROT (*Daucus carota*)		4.0-11.0	*Bb, Mm, Ti*	Gujarat[40]
	Harvesting	4.0-5.0	*Bb in summer*	
			Bb, Mp in kharif	Karnataka[42]
CUCUMBER (*Cucumis sativa*)	At maturity	8.8	*Bb, Ti*	Haryana[14]
	At maturity	4.8-19.9	*Bb, Ti*	Gujarat[1]
		5.0-10.0	*Bb, Ti, Mm*	Gujarat[40]
		upto 10.0	*Bb*	Karnataka[20]
MUSK MELON (*Cucumis melo*)	Unripe & ripe fruits	5.3 -9.6	*Bb*	Punjab[8]
	Ripe fruits	11.8	*Bb, Ti, Rm,*	Haryana[14]
FRENCH BEAN (*Phaseolus vulgaris*)		4.0-7.0	*Bb, Ti, Mm*	Gujarat[40]
		5.0	*Bb, Mp, Ti*	Karnataka[42]
BOTTLE GOURD (*Lagenaria siceraria*)	At maturity	14.6	*Bb, Ti*	Haryana[14]
	At maturity	4.1	*Ti, Mh*	Rajasthan[11]
	At maturity	4.1	*Bb, Ti*	Gujarat[1]
	At maturity	4.0 to 6.0	*Bb, Mm*	Haryana[48]
BEETROOT (*Beta vulgaris*)	Pre harvest	4.0	*Bb, Ti, Mp*	Karnataka[41]
CHOW-CHOW (*Sechium edule*)		0	*Bb, Mm, Mp*	Karnataka[41]
ONION (*Allium cepa*)		0	*Bb, Mb, Mp*	Karnataka[41]
RIDGE GOURD (*Lufta acutangula*)	At maturity	Upto 10.0	*Bb, Mm*	Karnataka[20]
SWEET POTATO (*Ipomuea batatus*)	Tubers	3.0-9.0	*Bb, Mm, Ti*	Gujarat[40]
		4.0	*Bb, Mm, Ti*	Karnataka[20]
SPONGE GOURD (*Lufa cylindrica*)	At maturity	9.8	*Bb, Ti*	Haryana[14]
CHILLI (*Capsicum annum*)	At maturity	3.5-11.7	*Bb, Ti*	Gujarat[1]
		4.0-6.0	*Bb*	Gujarat[40]
		0.6-1.0	*Bb, Ti*	Karnataka[47]
			Mp, Bb, Mb, Rr	H.Pradesh[44]
LUCERN (*Medicago sativa*)		5.0	*Bb, Ti, Mm*	Gujarat[40]
FRUITS				
WATER MELON (*Citrullus vulgaris*)	Ripe fruits	9.9-19.8	*Bb, Rm*	Punjab[15]
SUMMER SQUASH (*Cucurbita smoschta*)	At maturity	5.2-18.4	*Bb*	Punjab[8]
	At maturity	1.4 -1.6	*Bb, Ti*	Haryana[9]
APPLE (*Pyrus malus*)		17.0-40.0	*Bb, Rr, Mm, Ge, Mb*	H.Pradesh[44]
PEACH (*Prunus persica/ P.platycarpa*)		2.0-7.0	*Bb, Mm, Mb, Rr, Ge*	H.Pradesh[44]

Crops	Stage	Damage)/ YL (yield loss g/ha)	Species	State
PLUM		1.0-2.0	*Bb, Mm, Mb, Rr, Ge*	H.Pradesh[44]
BER (*Zizyphus jujuba*)	Nursery	8.0 - 80.0	*Ti, Fp, Mm, Mb*	Rajasthan[16]
PECAN, (*Carya illinoensis*)	Root damage	17.4 1.6-6.7	*Bb* *Bb, Mm, Mb, Rr, Ge*	H. Pradesh[17]
SAPOTA (*Acrus sapota*)	Ripening stage	5-10%	*Fp, Bb, Ti*	Karnataka[20]
PINEAPPLE (*Ananas comosus*)	Seminpe & ripe -do- Semiripe Ripening stage	8.5 4.7 44.4 2.6-17	*Rn, Bb* *Rm, Bb* *Rr* *Bb, Rn, Rr*	Meghalaya[18] Mizoram[18] Tamil Nadu[19] NEH region[43]
BANANA (*Musca sapientum*)	Fruits	1.0-2.0	*Bb*	Karnataka[20]
POMOGRANATE (*Punicia granatum*)	Fruits	6.1-11.3 10-12%	*Fp* *Fpm, Bb*	Rajasthan[16] Karnataka[20]
COCONUT (*Cocos nucifera*)	Root damage in nurseries Tender nuts Tender nuts Tender nuts Tender nuts Tender nuts Nuts	6.8-8.0 12.0-15.0 21.0-28.5 14.7 4.5-55.0 32.0 15.0 7.0-11.0	*Bb* *Fpm, Rr* *Rrw* *Rr* *Rr* *Rra* *Sv, Sc* *Rr*	Karnataka[21] Karnataka[7] Kerala[22] A. Pradesh[23] Lakshadweep islands[24] Andaman Islands[24] Tripura[25] Gujarat[40]
COCOA, (*The obroma cocoa*)	Pods Pods Pods	50.0 47.6 12.57 10.28 51.3-60.0	*Rrw, Ft* *Rrw, Ft* *Ft* *Rrw* *Rrw, Ft, Fpm*	Tamil Nadu[26] Karnataka[26] Karnataka[27] Karnataka[27] Kerala[32, 33]
CARDAMOM (*Elettaria cardamomum*)	Capsules Greenish yellow Capsules In plains In slopes Average	8.7-12.6 20.0 12.0 1.4 12.0	*Fpm, Bb* *Fpm, Bb*	Karnataka[28]
OIL PALM (*Elaeis guineensis*)	Seedlings Saplings Seedlings Saplings Tender & ripe nuts	45.0 11.2 10.0 29.5 50.0-57.3	*Rrw* *Bb* *Rra*** *Rra* *Rra*	Kerala[29] Tamil Nadu[30] Andaman[31] Andaman[31] Andaman[22, 31]
CASHEW (*Anacardium occidentale*)	Nuts Seedlings	5.7nuts/day -	*Rb, Bb* *Fpm, Bb, Hi, Rr*	Kerala[35] Kerala[36]
RUBBER (*Hevea brasiliensis*)	Nursery young plants	Root damage Debarking	*Bb, Bi* *Rm, Hi*	Kerala[37,38] Kerala[37,38]
ARECA NUT (*Arecha catechu*)	Nuts Nuts Flowering	432g/tree 20% 2.0-3.0	*Fpm* *Fpm*	Karnataka[20] Karnataka[34] Karnataka[20]

Ti-Tatera indica, Rm-Rattus meltada, Bb-Bandicota bengalensis; Mh-Meriq hurrianae; Mp-Mus platythrix, Ri Rattus rattus; Ge-Gollunda ellioti; Mb-Mus booduga; Rn-Rattus nitidus; Fp-Funambulus penti, Fpm-Funambulus palmarum, Rrw-R.r wroughtoni; Rra-R.r.adamanensis; Sv-Sciurus vulgaris, Sc-Sciurus carolinensis., Ft-Funaulus tristriatus, Rb-Rattus blanfordi, Hi-Hystrix indica.

(1)Rana *et al.*, 1994, (2) Neelanarayanan *et al.*, '1994a, (3) Ahmad & Parshad 1985 (4) Parshad, 1987 (5) Brar & Awasty 1982 (6) Singh *et al.*, 1988 (7) Chakravarthy, 1983 (8) Malhi & Parshad, 1992 (9) Pasahan & Sabhlok, 1993 (10) Kotadia *et al.*, 1993 (11) Advani & Mathur, 1982 (12) Anon, 2004 (13) Anon 1995 (14) Kumar & Pasahan, 1995 (15) Chopra & Parshad, 1986 (16) Rana *et al.*, 1999 (17) Sheiker & Jain, 1991 (18) Singh *et al.*, 1994 (19) Nagarajan *et al.*, 1994a (20) Sridhara, 1999 (21) Guruprasad & Srihari, 1983 (22) Advani, 1985 (23) Rao & Subiah, 1982 (24) Advani, 1984 (25) Sarkar, 1986 (26) Bhat *et al.* 1981 (27)Thyagaraj *et al.*, 1996 (28) Srihari & Chakravarthy, 1992 (29) Bhat *et al.*, 1990 (30) Nagarajan *et al.*, 1994b (31) Subiah, 1983 (32) Bhat, 1978 (33) Abraham & Remamony, 1999 (34) Nambiar, 1949 (35) Bhat, 1990 (36) Basheer & Jayaraj, 1964 (37) Jayarathnam, 1980 (38) Nehru & Jayarathnam, 1985 (39) Naidu, 1949 (40) Butani & Vyas, 2005 (41) Anon 2004 (42) Anon 2005 (43) Pathak & Kumar, 2001 (44) Sharma, 2005 (45) Sheikher & Jain, 1997 (46) Chopra & Kapoor, 1993 (47) Govind Raj & Srihari, 2000 (48) Chopra *et al.*, 1999.

Kerala: Cropwise data on species affecting is not available. But plantation crops such as coconut, areca nut, rubber, cashew and cocoa were damaged by *R.rattus, R.r.wroughtoni, F.tristriatus, F.palmarum, B.indica* and *B.bengalensis*. Other species reported were *T.indica, M.booduga, H.indica* and *V.oleracia*.

Madhya Pradesh: *B.bengalensis, M.meltada* and *R.rattus* damaged paddy, *T.indica, B.bengalensis, M.meltada* and *M.booduga* infested rice, maize and jowar fields. Pulses were damaged by *M.meltada, B.bengalensis* and *R.rattus*. Pests of soybean were *R.rattus, B.bengalensis* and *M.meltada*.

Maharashtra (Non AICRP reports): *R.rattus, B.bengalensis, M.booduga, M.platythrix, T.indica, G.ellioti, H.indica, F.pennanti* and *F.tristriatus* reported from cultivated fields (Table 4).

NEH region: Rice was damaged by *B.bengalensis, R. nitidus* and *M.booduga* while maize was affected by *B.bengalensis, R.rattus* and *M.booduga. B.bengalensis* infested legumes and soybean. *B.bengalensis* and *R.nitidus* damaged groundnut. Pine apple orchards were infested by *B.bengalensis, R.nitidus* and *R.rattus*. Animal facilities were inhabited by *R.rattus, M.booduga* and *B.bengalensis*.

Punjab: Wheat was infested by *B.bengalensis, T.indica, R.meltada* and *G.ellioti*; rice by *B.bengalensis, R.meltada, T.indica* and *G.ellioti* and groundnut by *T.indica, R.meltada, B.bengalensis, M.musculus* and *M.booduga*. Sugarcane pests were *B.bengalensis, T.indica, R.meltada* and *Mus* species.

Rajasthan: *M.hurrianae* and *T.indica* are the major pests of pearl millet, green gram, moth and bean. Near sand dunes *G.gleadowi* also damages the rainfed crops. In groundnut, cotton, wheat, mustard and cumin, *T.indica, M.meltada* and *M.hurrianae* are the pests. In the canal command areas *T.indica, M.meltada M.booduga, B.bengalensis* and *N.indica* infest. *F.pennanti* was a pest on orchard crops. *B.bengalensis* is progressively invading irrigated crop fields.

Sikkim: *B.bengalensis, R.rattus rattoides,* voles reported.

Tamil Nadu (Non AICRP reports): *B.bengalensis, M.booduga, M.meltada, T.indica* were the major rodent pests of crops (Table 4).

Tripura: *B.bengalensis* and *Rattus sp.*

Table 4 : Species composition of rodents in crop fiels in states not covered by (AINP) on Rodent Control

State	Crops						
	Paddy	Wheat	Ground Nut	Ragi	Cultivated fields	Rice+ Wheat	Soybean
ANDAMAN & NICOBAR ISLANDS	NA*	NA	NA	NA	*Mc*[1]	NA	NA
ARUNACHAL PRADESH	NA	NA	NA	NA	*Mb*[2]	NA	NA
BIHAR	*Bb*[3]	NA	NA	NA	NA	NA	NA
GARHWAL HIMALAYAS	*Bb, Mb, Mc, Mms, Ni*[4]	NA	NA	NA	NA	NA	NA
HARYANA	NA	*Bb>Rm> Ti>Mb* 90.65kg/ha[5]	NA	NA	NA	NA	NA
MAHARASHTRA	NA	NA	NA	NA	*Bb, Mb, Mp, Ge, Ti, Ft, Hi*[6]	NA	NA
TAMILNADU	*Bb>Mm>*[7]*Mb*	NA	*Bb>Mm>M*[8]	NA	NA	Cotton *Bb>Mm>Mb*[9]	Sugarcane *Bb>Mm> Mb*[9]
UTTAR PRADESH	NA	*Bb, Ti, Mm*[12]	NA	NA	*Bb, Mm, Mb*[11] *Bb>Ti>Mb> Mm>Ni, Ge, Vo*[15]	*Bb, Mp, Rr*[14]	NA
WEST BENGAL	*Mm*[16] *Bb*[17]	NA	NA	NA	Mp[1]	NA	NA
SIKKIM	NA	NA	NA	NA	*Bb, Mph, Mm, Red Reh, Rff, Rnv, Rn, Rrt, Rrr, Rrb, Vo, Hh,* Vole marmot[10] and species of squirrels[11]	NA	NA

Mph - Mus pahari pahanri; Red - Rattus edwardsi edwardsi Reh - Rattus eha eha; Rff - Rattus fulvescens fulvescens; Rnv - Rattus niviventer lepha; Rn - Rattus nitidus tidus; Rrr - Rattus rattoides rattoides; Rrt - Rattus rattus tistae; Rrb - Rattus rattus brunnesculus; Vo - Vandeleria oleracea dumeticola; Mc-Mus cervicolor; Mms-Mus musculus; Bb-Bandicota bengalensis; Ni-Nesokia indica;Mb-Mus booduga; Ti-Tatera indica; Ft-Funambulus tristriatus, Ge-Golunda ellioti; Hi-Hystrix indica; Rr-Rattus ratus; Hh-Hystrix hodgsoni; NA* Not available.

(1) Mandal & Ghosh, 1984; (2) Mandal, 1981; (3) Bannerje, 1996; (4) Sheikher *et al.*, 1983; (5) Singal & Pasahan, 1995 (6) Pradhan, 1989; (7) Neelanarayanan *e.al.*, 1995; (8) Ibid, 1996; (9) Ibid, 1997; (10) Bhaskaran *et al.*, 1995; (11) Mandal, 1982; (12) Mathur *e.al.*, 1996; (13) Mathur & Bhaduria, 1998; (14) Srivastava *et al.*, 1983; (15) Bhaduria & Mathur, 1994; (16)Mandal & Ghosh, 1980; (17) Chakraborty, 1975.

Uttar Pradesh: Sugar cane was damaged by *B.bengalensis, R.meltada, T.indica* and *M.booduga*. Species reported for wheat and rice are *B.bengalensis, T.indica, M.meltada, N.indica, M.platythrix, R.rattus, M.booduga* and *M.cervicolor*.

Extent of damage: The range of damage to food crops and commercial crops viz. fruits, vegetable and plantation crops are depicted in Figures 1 and 2. Amongst food crops maximum damage occurs in pearl millet, jowar and red gram at seedling stage/sown seeds. The other crops damaged upto 10% and above are, wheat, rice, pearl millet, finger millet, maize, jowar, Bengal gram, green gram, cow pea and groundnut.

Amongst non-food crops, maximum damage was seen for Ber followed by cotton (seed), coconut, cocoa, oil palm and apple. Considerable losses were inflicted to sugarcane, cucumber, water melon, pecan, pine apple and areca nut. Damage to carrot, musk melon, bottle gourd, chillies, summer squash, sapota and pomegranate, was also around or above 10%. This consolidated data from all over the country qualifies rodents as serious pests of almost all cultivated crops in India.

Information is available from publications made now and then on rodent pest species in states where AICRP on Rodent Control is not operating, (Table 4). Information is awfully lacking for Andaman & Nicobar Islands, Orissa, Bihar, Uttaranchal, Maharashtra and West Bengal. The two exceptions are Tamil Nadu and Uttar Pradesh where some committed effort is seen on the role of rodents in crop fields (Neelanarayana *et al.*, 1995, 1996 and 1997; Srivastava *et al.*, 1983; Srivastva 1992 and Bhaduria & Mathur, 1994). *B.bengalensis, M.meltada, T.indica* and *M.booduga* are the major pests in Tamil Nadu. Uttar Pradesh has a rich complex of rodent pests comprising of *B.bengalensis, M.meltada, M.booduga, M.platythrix, T.indica, G.ellioti, V.oleracia* and *R.rattus*. Generally *B.bengalensis, M.meltada, M.booduga* are seen in most of the states. *N.indica* is limited to north and north-west India. *T.indica* is ubiquitous. Sikkim has very rich rodent fauna (Mandal, 1982), but their status is yet to be determined.

The data compiled in this compendium demonstrates beyond doubt the extensive damage caused by rodents to almost all cultivated crops in India. The relative abundance of species, the occurrence of different species complexes in different agro- climatic zones of the country, the biology of the species, the extent of damage, the vulnerable stages of crops susceptible to rodent depredation have been well documented across the country, in most of the states. This information is expected to contribute significantly in improving rodent management strategies for different cropping systems and crops in the country.

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