Current Status of Rodent Problem in Indian Agriculture

Neena Singla

(Punjab Agricultural University, Ludhiana, Punjab)

Vipin Chaudhary & R.S. Tripathi

(ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan)

NETWORK COODINATING UNIT

All India Network Project on Vertebrate Pest Management

ICAR-Central Arid Zone Research Institute

(ISO 9001 : 2015)

Jodhpur - 342 003 (Rajasthan)

2017

Current Status of Rodent Problem in Indian Agriculture

Neena Singla
(Punjab Agricultural University, Ludhiana, Punjab)

Vipin Chaudhary & R.S. Tripathi
(ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan)

NETWORK COODINATING UNIT
All India Network Project on Vertebrate Pest Management
ICAR-Central Arid Zone Research Institute
(ISO 9001 : 2015)
Jodhpur - 342 003 (Rajasthan)

2017

Technical Bulletin No. 20

Published by
AINP on Vertebrate Pest management
For Indian Council of Agricultural Research
ICAR-Central Arid Zone Research Institute, Jodhpur-342 003

Authors
Neena Singla
Punjab Agricultural University, Ludhiana, Punjab

Vipin Chaudhary and R.S. Tripathi,
ICAR- Central Arid Zone Research Institute, Jodhpur-342 003

Printed at : Evergreen Printers, Jodhpur #9414128647

सत्यमेव जयते

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एम ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

Trilochan Mohapatra, Ph.D.
FNA, FNASc., FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं भारतीय कृषि अनुसंधान परिषद्
कृषि एवं किसान कल्याण मंत्रालय
कृषि भवन, नई दिल्ली 110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
KRISHI BHAVAN, NEW DELHI 110 001

Message

Rodents, the most successful and abundant mammalian group on earth today probably next to man, share human and animal habitats for food and shelter. Out of over a hundred rodent species occurring in India about over a dozen species are categorized as problem species in Agriculture, storage and public health. Indian Council of Agriculture feels pride in being the pioneers in undertaking R&D activities on applied rodentology in the country through this Network Project.

For evolving an integrated approach for rodent pest management, knowledge about the target species and its pestilence is the first and foremost requirement. I am happy that the AINP scientists stationed at various agro-ecologies of the country have strived hard in generating a very useful information on rodent pests, their distribution and extent of damage to various crops at national level. The present compilation is an excellent attempt to collate the information generated during last 7-8 years.

I appreciate the efforts of all the Project scientists in generating such an information and congratulate the authors in bringing out a current status of rodent problem in form of a technical bulletin. I am sure that the information contained in this publication would be of immense help to the scientists and researchers and policy makers in developing and disseminating region/crop specific rodent management strategies for enhanced food security.

Dated the 24th October, 2017
New Delhi

(T. MOHAPATRA)

भारतीय कृषि अनुसंधान परिषद
Indian Council of Agricultural Research
कृषि भवन, डॉ. राजेन्द्र प्रसाद रोड, नई दिल्ली 110001
Krishi Bhavan, Dr Rajendra Prasad Road, New Delhi 110001

Dr. P.K. Chakrabarty, *PhD., FNAAS*
Adjunct Professor, UF
Asst. Director General (PI Protection & Biosafety)

Message

Rodent pests cause severe losses to agriculture at pre as well as post-harvest stages across different production systems in the Country. Their damage propensities in rangelands, afforestation sites, fruit orchards and plantation crops is also well known. Changes in land use patterns, climatic variability, urbanization and several other human activities have led to changes in rodent species composition and their pestilence across the country. The spread of lesser bandicoot rats, *Bandicota bengalensis* in new areas, from extremes of arid regions in western India to far North- east in Arunachal Pradesh and even to Andaman and Nicobar Islands in recent years is a matter of serious concern. It was therefore felt to compile the information generated on current status of rodent pest species and their damage potentials to different crops at National Level.

The present publication therefore attempts to collate such information generated at different cooperating centers of the All India Network Project on Vertebrate Pest Management in form of present bulletin. I am thankful to the Network Coordinator in initiating this endeavor to publish a bulletin on this aspect. I feel immense pleasure in appreciating all the Project scientists for generating such a useful information and congratulate Drs. Neena Singla, Vipin Chaudhary and R.S. Tripathi for collating the information in its present form.

I am confident that the bulletin on "Current status of rodent problem in Indian Agriculture" will be useful to the project scientists and other researchers in understanding the rodent pest composition and damage inflicted by them in agriculture which in turn would help evolve region/ crop specific rodent management strategies. The publication will also serve as a valuable resource document to create awareness about rodent problem among students, scientists, policy planners and extension functionaries alike.

Dated the 20th October, 2017
New Delhi

(P.K. Chakrabarty)

Preface

With the onset of green revolution and adoption of improved crop production and protection technologies, Indian agriculture shifted from a natural, subsistence type farming to a managed, intensive agricultural practice. As a result of such developments, the population of more opportunistic animals including rodents increased a lot. Rodents belong to the largest order Rodentia of class Mammalia and constitute 43% of the total mammalian fauna. Their species are distributed on every continent except Antarctica. These include porcupines, squirrels, voles, marmots, moles, rats, gerbils, mice etc. Among mammalian pests, rodents rank first by virtue of damage they inflict on almost all cultivated crops at one stage or the other.

The history of agriculture in India dates back to the Rig-Veda. Today, India ranks second worldwide in farm output. Agriculture and allied sectors like forestry, livestock, logging and fisheries accounted for 18% of the GDP (Gross Domestic Product) in 2015. Though, the economic contribution of agriculture to India's GDP is steadily declining with the country's broad-based economic growth, still, agriculture is demographically the broadest economic sector and plays a significant role in the overall socio-economic fabric of India.

The major thrust of the ICAR sponsored All India Network Project on Vertebrate Pest Management has been to generate knowledge on rodent species, damages caused and to evolve rodent pest management strategies for major crops and cropping systems in the country. The Project since inception has generated sufficient data on rodent fauna and damage providing base line for development of practical workable rodent management technologies across the country. Present publicatioin is an attempt to compile the information on major rodent pest species of the country, their distribution and damages caused in agriculture in recent years.

The efforts made by Project scientists across the country in providing necessary information is greatly acknowledged. We would like to sincerely thank Drs. G. Govindaraj and Mohan I. Naik (UAS, Bengaluru), Ratul Borah (AAU,

Jorhat), A. Birah and T. Bharathimeena (CIARI, Port Blair), Madan Mohan Kumawat (CAU, Pasighat), K. Nanda Kishore and N. Srinivasa Rao (ANGRAU, Maruteru) and Dr B.K.Sahoo (OUAT, Bhubaneswar).

We extend our deep sense of gratitude and thanks to Dr. P.K. Chakrabarty, Assistant Director General (Plant Protection & Bio safety), ICAR, New Delhi for providing constant support to the Project and encouragement in bringing out this publication.

We are extremely grateful to the Indian Council of Agricultural Research, New Delhi and Director, ICAR- Central Arid Zone Research Institute, Jodhpur for providing financial assistance and administrative approval and other necessary facilities for publication of this compendium.

Neena Singla
Vipin Chaudhary
R.S. Tripathi

CONTENTS

INTRODUCTION

India is a multifaceted country with huge regional span. There is an excellent diversity of topography, natural features, cultures, traditions, people, languages and economic features in the country. Sustaining this kind of diversity is not an easy task. Even, it would not be fair to present all the features under one region. To give every region and feature its due regard, India can be divided into eight zones based upon climatic, geographical and cultural features. Each zone is further comprised of certain number of states and union territories. In all, there are 29 states and seven union territories.

1. **North Zone:** This zone houses the states of Jammu and Kashmir, Himachal Pradesh, Punjab, Uttarakhand, Uttar Pradesh and Haryana. This zone is also the home to mighty Himalayas and other mountain ranges.
2. **East Zone:** This zone is comprised of states of Bihar, Odisha, Jharkhand and West Bengal. This region is rich in minerals, flora and fauna in dense forests.
3. **North-east Zone -** Assam, Sikkim, Nagaland, Meghalaya, Manipur, Mizoram, Tripura and Arunachal Pradesh are located in this zone.
4. **North-west Zone:** This zone has the states of Rajasthan, Gujarat, Goa and Maharashtra.
5. **Central Zone:** Madhya Pradesh and Chhattisgarh are the only occupants of this zone. Being a plateau region, it is rich in minerals and is also home to many famous wildlife sanctuaries, national parks and bio-reserves.
6. **South Zone:** States of Andhra Pradesh, Telangana, Karnataka, Kerala and Tamil Nadu occupy this zone. The zone is flanked by oceans on three sides and therefore, home to scenic beaches.
7. **South-east Zone:** Andaman and Nicobar Islands occupy the South-east zone of India.
8. **South-west Zone:** Islands of Lakshadweep occupy the South-west zone of India.

Since its independence, India has made immense progress towards food security. It has become one of the world's largest producer of rice, cotton, sugar and wheat. As per the FAO world agriculture statistics 2010, India is the second largest producer of wheat and rice, the world's major food staples. India is also the world's second or third largest producer of several dry fruits, agriculture based textile raw materials, roots and tuber crops, pulses, farmed fish, eggs, coconut, sugarcane and numerous vegetables. India rank within the world's five largest producers of over 80% of agricultural produce, including many cash crops such as coffee and cotton.

The country has shown a nationwide steady annual increase in various agricultural items, over the last 60 years. These gains have come mainly from India's green revolution which began with the decision to adopt superior yielding, disease resistant wheat varieties in combination with better farming knowledge to improve productivity. The initial increase in production was centred on the irrigated areas of the Indian states of Punjab, Haryana and western Uttar Pradesh. With both the farmers and the government officials focusing on farm productivity and knowledge transfer, India's total food grain production soared. Punjab led India's green revolution and earned itself the distinction of being the country's bread basket.

However, despite these accomplishments, crop yields in India are still just 30 to 60% of the best sustainable crop yields in comparison to developed and other developing countries. Additionally, losses after harvest due to poor infrastructure cause India to experience some of the highest food losses in the world.

Recent studies claim that India can easily feed its growing population, in addition to producing wheat and rice for global exports, if it can reduce food staple spoilage, improve its infrastructure and raise its farm productivity to those achieved by other developing countries such as Brazil and China. With the onset of green revolution and adoption of improved crop production and protection technologies, Indian agriculture shifted from a natural, subsistence type farming to a managed, intensive agricultural practice. As a result, the population of more opportunistic animals including rodents has increased a lot.

Rodents are serious pests in agricultural and commensal situations. They frequently thwarts our efforts towards improving food supply to increasing human population by causing severe damages and economic losses during production, transport and storage of food. Quantification of exact losses to agricultural production due to rodents is often difficult due to multivariate nature of their direct and indirect damages and variations in the intensity and rate of infestation. In addition, rodents also act as reservoirs of many diseases of mankind and its livestock.

Rodents derived their name from their gnawing behaviour (Latin: rodere = gnaw). They have chisel shaped sharp incisor teeth that grow constantly and need to be used, otherwise they will grow back into the cheek disabling proper feeding. Rodents have well developed senses of smell, touch and hearing, but poorly developed eyesight. Although most rodents live for only about one year, they are prolific breeders and multiplying rapidly under most favourable conditions.

Rodent pest species are omnivorous. The quantity of food taken may vary because under laboratory conditions, rodents consume about 10% of their body weight per day, however, in field conditions the quantity consumed or destroyed is more than five times. Thus, actual losses caused by rodents are a multiple of their dietary requirements.

The rodent fauna of the India is represented by 46 genera and 103 species. Of these over a dozen species are commensal and agricultural pests. A large quantity of crops during pre- and post-harvest periods are lost annually due to rodents. Their damage is more serious at seedling and ripening stages of the crop. Analysis of data on the damage and economic losses caused by rodents at pre-harvest stage indicates a range of 2-15% to major crops. Rice, wheat, sugarcane, groundnut, forage crops are the worst sufferers due to rodent attack. Among plantation crops coconut experiences severe nut damage by a subspecies of house rats. Due to their fast adaptability to changing climatic conditions, several areas in the country became endemic to rodents. The near total losses of rice and maize in Mizoram and in several other northeastern states during gregarious flowering of bamboo are examples of such outbreaks. At post-harvest stage, rodents are held responsible for a loss of 5% food grains annually in Southeast Asia.

Animal houses, particularly poultry farms, provide a most favourable and stable habitat throughout the year for large rodent populations. Rodents cause a serious threat to poultry by feeding on poultry feed, contaminating it with their excrements, damaging eggs, attacking and killing chicks, causing structural damage to buildings, doors, windows and feed containers. The reasons for the subsistence of large rodent populations in most of the storage premises and animal and human dwellings is due to inadequate maintenance of buildings combined with lack of hygiene, poor handling of food materials leading to spillage and serious neglect of rodent proofing.

Rodents are also important vectors or reservoirs of numerous diseases that infect humans, domestic animals and other wildlife species. In addition, rodents also destroy food by contaminating with their urine, faecal droppings and hair.

With increase in urbanization and inadequate waste disposal, the habitat has become conducive for rodent breeding and the rodent problem is on increase. Similarly, in Indian Railways, the rodents pose a problem in railway coaches threatening health and fire hazard problems. The pipes, cables, drip systems are being damaged quite often by rodents. The rodent problems are increasingly felt in almost all sectors viz., food and breweries, telecommunication, aviation, IT, hospitals, food establishments, shopping malls etc.

RODENT SPECIES OF ECONOMIC IMPORTANCE

1. **Squirrels:** The Northern Palm or Five Stripped Squirrel, *Funambulus pennanti* is a medium sized rodent weighing 90g with a bushy tail. The dorsal side is greyish brown with five distinctly white stripes separated by four off white bands. Its distribution ranges from south of Sikkim to the northern Karnataka, from Rajasthan to West Bengal and also in Andaman Island. The squirrel is diurnal and generally lives close to human habitation, orchards, gardens, parks and in areas with fairly good number of trees. Breeding is generally seasonal from March to September with peaks during March–April and July-September in Rajasthan. Litter size varies from 1-5. Another species, viz., Southern Palm Squirrel, *F. palmarum* is the counter part of *F. pennanti* in southern India which possesses three white bands on the dorsal side separated by two off-white bands. The third species viz., the Western Ghat squirrel, *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. It has a limited distribution in western and south western India mostly in the Western Ghats. It breeds round the year with peaks occurring from December to May. It causes severe loss to cocoa and other plantation crops.

2. **The Indian crested porcupine, *Hystrix indica*:** The crested porcupine is the largest rodent species in India measuring 680-750 mm in length and weighing 11-18 kg. The neck and upper back are covered with distinct long, stiff, bristle-like hairs called quills (15-30 cm). 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. It is widely distributed in India and is a nocturnal animal. Porcupines breed throughout the year with a litter size of 1-8. The porcupines feed on succulent tubers, bulbs, ripe fruits and bark of trees.

3. **The lesser bandicoot rat, *Bandicota bengalensis:*** It is a robust rodent with a round head and a broad muzzle weighing 200-350 g. 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. Except in extreme arid tracts of western Rajasthan, *B.bengalensis* is widely distributed throughout the country even up to far north east in Arunachal Pradesh and in Andaman & Nicobar Islands. It is a fossorial animal and is well adapted to various habitats and ecological conditions which include cultivated fields, pastures, forests, mountains, inter-tidal mangrove zones, semi-arid zones and also as a commensal in towns and cities across India. It also breeds throughout the year with a litter size of 4-12.

4. **Larger bandicoot rat, *Bandicota indica*:** It is a very large sized rat with head and body normally ranging 200-366 mm. Weight ranges from 500 g to 2 kg or more. Tail is shorter than head and body (HB) length and is covered with hairs 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. In India its distribution ranges from south of Rajasthan down to southern tip of India and eastwards too. The larger bandicoots always lives close to human habitations. The species is nocturnal and fossorial. It breeds all around the year but has a seasonal reproduction peaks from September to March in India.

5. **Indian gerbil, *Tatera indica:*** It is a medium sized rodent weighing about 100-150g. The tail is longer than HB and possesses tuft of hair at the tip (characteristic of all gerbils). The hind feet are longer than fore feet. The species is ubiquitous in distribution occurring throughout India except the hills. The species inhabits open plains, loose sandy soils of the desert, and is usually found at the edges of cultivation. Gerbils are nocturnal and breeds throughout the year in arid Rajasthan with maximum littering in the month of August and a minor peak in February with a litter size of 1-9. *T. indica* is also regarded as reservoir of plague bacteria.

6. **Indian desert gerbil, *Meriones hurrianae:*** The species is restricted to north-west desert of Rajasthan, north-west Gujarat and Punjab. The adult body weight of *M. hurrianae* is 40-160 g., 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. The gerbils prefer sandy habitat of arid zones. They are diurnal and live in smaller colonies. They breed throughout the year with two peaks in February and July with a litter size of 1-9.

7. **Short tailed mole rat, *Nesokia indica:*** The species is heavily built weighing more than 200 g. The dorsum is dull to brown with lighter ventral side. Tail is short. Fur is short and rough. The species is mainly reported from North India, Punjab, Rajasthan, Haryana, Uttar Pradesh, Himachal Pradesh and Delhi. It prefers bunds in cultivated fields along water channels but also occurs in natural vegetation and garden lawns. The species is nocturnal with a bimodal circadian rhythm and fossorial. Although it breeds throughout the year under laboratory conditions, in nature breeding occurs only during winter with a litter size of 2-5.

8. **The soft furred field rat, *Millardia meltada:*** The species also referred as metad is distributed throughout India, except the north eastern hill regions. Body colour light to dark grey dorsally with foot and belly being off white. Tail is similar to body colour with dark grey above and pale below. The animals weigh between 40-70 g. It is one of the most

predominant rodent pests in almost all the states. It is a nocturnal animal and makes simple burrows. In Rajasthan metads breed throughout the year with peak reproduction occurring in spring and monsoon season.

9. **The house rat, *Rattus rattus:*** It is a medium sized rat weighing 150-200 g called as roof rat, black rat, ship rat etc and is the most abundant and widely distributed species in India as well as the world. It is characterized by long tail, slender body and pointed snout. The dorsal fur is mostly blackish in commensal forms which range to yellow to brown black with pale white belly in wild forms. It is nocturnal and colonial and lives in houses, godowns, stores, poultry farms, crop fields adjacent to villages. House rats breed throughout the year, with a litter size of 1-9. A sub species of *R. rattus* i.e., *R. rattus wroughtoni* commonly referred as Wroughton's rat weighing around 95 g is regarded as serious pest of plantations crops like coconut and cocoa. It is abundantly found in southern India from the semi evergreen forests, scrub jungles, coconut plantations of Karnataka, Kerala, Andhra Pradesh. It is an arboreal rodent spending more than 80% of time on tree tops. It lives in nests constructed in tree holes in forests and either in the inter-space of nuts or inside stipules in the spindle portion of coconut.

10. **Himalayan rat, *Rattus nitidus*:** It is a medium sized rodent weighing 100-175 g and has been reported from all the states of NEH region. Dorsum usually dark brown, occasionally with a darker mid dorsal patch. Ventrum is silvery gray or off-white. Tail is compeletly dark and naked. It is regarded as pest under commensal situations, also in fields causing damage to pine apple, rice, maize etc in NEH regions.

11. **House mouse, *Mus musculus*:** House mouse is very small rodent weighing 15-20 g and is widely distributed in India and the world. The tail is naked and longer than the head-body length. Dorsally, the colour varies from brown to light brown with belly being whitish or light grey. It is nocturnal in habit nesting in rafts, crevices in walls, amidst staked undisturbed bags of food grains in godowns, table drawers, often lives in fields by digging burrows. The mouse breeds round the year with a litter size of 1-8. In fields it is known to damage sugarcane, groundnut etc.

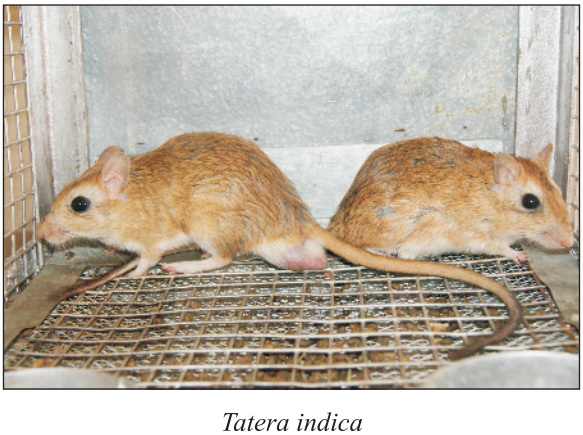
12. **Indian field mouse, *Mus booduga*:** This tiny mouse is distributed all over India. Recently, the species has also been reported from Andaman and Nicobar Islands and Leh- Ladakh regions. The animal weighs between 10-15 g. Colour of dorsum varies from dark brown to lighter sandy brown with under parts whitish to slightly grey. Tail is bicoloured and shorter than HB length. This nocturnal and fossorial mouse makes simple burrows with characteristic scooped soil near openings. Peak breeding is noticed during September October and February to June with a litter size of 6-13.

Funambulus pennanti

Hystrix indica

Bandicota bengalensis

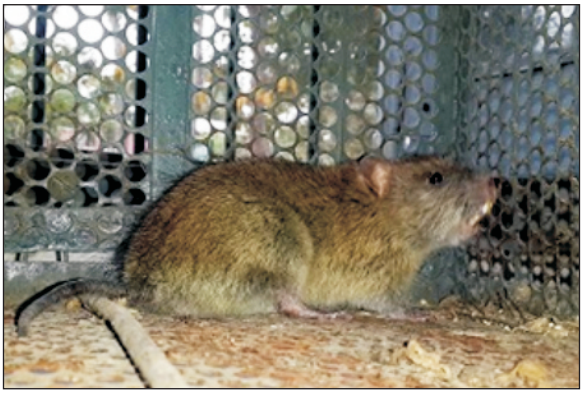
Bandicota indica



Tatera indica

Meriones hurrinae

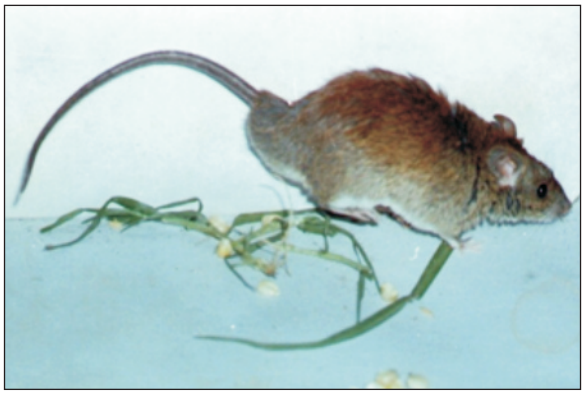
Plate 1: Major rodent pest species of the country



Nesokia indica

Millardia meltada

Rattus rattus



Rattus nitidus

Mus musculus

Mus booduga

Plate 2: Major rodent pest species of the country

STATE WISE INFORMATION ON RODENT PEST FAUNA AND DAMAGE

During last decade, sufficient data has been generated on rodent fauna and damages caused to different crops by different AINP centers located in various agro-ecologies of the country (Fig. 1). These include Punjab Agricultural University, Ludhiana (Punjab) in North zone; Assam Agricultural University, Jorhat (Assam) and Central Agricultural University, Pasighat (Arunachal Pradesh) in Northeast Zone; Orissa University of Agriculture and Technology, Bhubneswar (Odisha) in Eastern zone; Central Arid Zone Research Institute, Jodhpur (Rajasthan) in West Zone; ANG Ranga Agricultural University, Maruteru (Andhra Pradesh) and University of Agricultural Sciences, Bengaluru (Karnataka) in South Zone; Central Island Agricultural Research Institute, Port Blair (Andaman & Nicobar Islands) in Southeast zone.

Fig.1. Centers of AINP on VPM (Rodent Control)

1. ANDAMAN AND NICOBAR ISLANDS

The center of AINP on VPM (Rodent Control) for Andaman and Nicobar Islands is working at ICAR- Central Island Agricultural Research Institute (CIARI), Port Blair since 2009-10. Prior to that scattered reports about rodent fauna by Zoological Survey of India was available but not much was known about rodent pestilence from the Islands. CIARI center initiated surveys and reported occurrence of different species of rodents from the Andaman and Nicobar Islands.

Earlier reports indicated occurrence of 15 rodent species to inhabit the Andaman and Nicobar islands which included 13 species/ sub species under genus *Rattus*. The species included *R. rattus, R. burrescens, R. burrulus, R. burrus, R. palmarum, R. pulliventer, R. rogersi, R. stoicus* and *R. taciturnus*. Besides 5 sub species of *Rattus rattus* viz., *R.r. alexandrinus, R.r. andamanensis, R.r. atridorsum, R.r. flebilis* and *R.r. holechu* have been reported. Other species were *Mus musculus* and *Funambulus pennanti.* Three species viz., Zelebor's Nicobar rat (*R. palmarum);* Miller's long footed rat *(R. stoicus)* and *R. burrus* are endemic to these islands. *R. stoicus* and *R. palmarum* were major rodent species of Nicobar Islands.

Surveys undertaken by AINP scientists indicated occurrence of four new species/ sub species, viz., *Mus booduga, Cremnomys cutchicus, Rattus tanezumi andamanensis* and *Bandicota bengalensis* from Islands. *Rattus rattus* specimens were collected from coconut, areca nut, rice, cashew and gauva fields from different locations of South Andaman. *M. booduga* and *C. cutchicus* were collected from household and storage of south Andaman whereas *Rattus tanezumi andamanensis* was collected from household, coconut and gauva fields of south Andaman. *Mus musculus* were reported from household and rice fields of Andaman and *B. bengalensis* from rice fields. *R. stoicus* and *R. palmarum* inhabited oil palm and coconut plantations of Nicobar Islands. *Rattus burrus* occurred near household areas of Nicobar Islands. The species recorded for the first time by project scientists and endemic species to these islands are as under:

1. **Indian field mouse, *Mus booduga*:** The Indian field mouse (*Mus booduga*) has been reported for the first time from Andaman Island. These were collected from Garacharma location of south Andaman. The dorsal side is grey whereas the ventral is greyish white in colour. The average body weight of mouse collected from Andaman ranged between 9.3 - 10.1 g with a slender and naked bicolor tail. Total body length of Andaman collections of *M.*

booduga ranged between 132-147 mm and the juveniles were between 132-137 mm. (Mean: 139.5 mm). The head – body length ranged between 58-68 mm.

2. **The Cutch rock-rat, *Cremnomys cutchicus*:** The dorsal side is greyish whereas the ventral is greyish white in colour. The average body weight of rat ranged from 98 - 168 g with a slender short and naked, bicolor tail.

3. **Lesser bandicoot rat, *Bandicota bengalensis*:** The lesser bandicoot rat was found in few locations of rice fields in south & north Andaman. The dorsal side is dark grayish brown whereas the ventral is ash white in colour. The average body weight of rat collected from Andaman ranged from 155 - 254 g with hairy, chubby and naked body.

Endemic rodent species in Andman and Nicobar Islands: Miller's long footed rat, *Rattus stoicus* and Zelebor's Nicobar rat, *Rattus palmarum* and The Nonsense rat, *Rattus burrus* were major rodent species of Car Nicobar islands. These three species are endemic to the islands.

1. ***Rattus stoicus*:** This species proved to be most ubiquitous in the residential premises as well as in plantation orchards. The species is capable of climbing very tall plants and commonly nests in the crown of such trees. This species is endemic to the Andaman group of islands of India. Now it has also been recorded from Nicobar group of islands also. It is a terrestrial and nocturnal species and occurs in tropical evergreen forests. The dorsal side was light brown whereas the ventral was ash white. The average body weight of rat collected from Nicobar was 99 g (range 39-397 g) with chubby and naked, bicolor tail.

2. ***Rattus palmarum*:** This species is also endemic to India and was first reported by Zelebor in 1869. This species is listed as vulnerable because it is known from only two locations (Car Nicobar and Great Nicobar Islands). The species is endemic to Nicobar Islands and is restricted in less than 1200 km^2. It is a nocturnal and arboreal species. It has been found to prefer crowns of palm trees. The dorsal side is greyish brown whereas the ventral is ash white in colour The body weight of rat collected from Nicobar ranged from 37 - 209 g.

3. ***Rattus burrus*:** The species first reported by Miller in 1902 is endemic to Nicobar group of Islands and is listed as vulnerable species. The species occurs in tropical evergreen and semi-evergreen forests. The dorsal side is light brown whereas the ventral is ash white in colour. The body weight of rats collected from Nicobar ranged between 72 -152 g.

Rodent damage: Rice which is the second most cultivated crop in Andaman and Nicobar Islands suffers rodent attack at all the stages of growth. They cut the newly transplanted seedlings/ tillers by making diagonal cut normally 5-10 cm above the water level or uproot the new seedlings. The damage can be easily recognized when the tillers are thickened and possess hallow tubular cross section. Damage to rice crop ranged from 3.66 to 22.50% in the Islands.

Survey of coconut plantations during the years 2009-12 in south Andamans revealed rodent infestation levels ranging from 2.5-74.5%. The damage to coconuts varied from 4.2-6.2%. In Little Andamans, the rodent infestation levels ranged between 12.6-65.2% whereas the nut damage levels went as high as 5.9%. In Neil and Havelock Islands, the maximum nut damage recorded was 5.6 and 4.4%, respectively. Rodent infestation in Areca nut plantations in south Andaman was more in nursery stage of the crop. The rodent infestations ranged from 4.32 to 76.33% (Av. 21.46%).

In brinjal crop, the per cent rodent infestation during October to December, 2012 ranged from 5.7-46.6% in south Andamans. In the same period damage ranging from 8.3 to 33.9% were recorded in tomato crop. Rice faced huge losses due to rodent pests with damage varying between 3.7 to 18.2% in south Andamans and maximum damage of 21.7% in north Andamans.

2. ANDHRA PRADESH

The centre of AINP on VPM (Rodent Control) for Andhra Pradesh is working at AP Rice Research Institute of Acharya N. G. Ranga Agricultural University, Maruteru (West Godawari Distt). Rice is the major crop grown, followed by groundnut, sugarcane and maize. In addition, plantation crops such as coconut and cocoa are also grown. In the last 7-8 years, rodent damage has been recorded in various agro-climatic zones of Andhra Pradesh such as Godavari zone, Rayalaseema zone, High altitude zone, North coastal zone and Krishna zone.

Rodent species complex in Godavari zone having rainfall 800-1100 mm, consisted of lesser bandicoot rat, *Bandicota bengalensis* as the predominant species followed by house rat, *Rattus rattus* and field mouse, *Mus booduga.* In this zone, major crops grown are rice, sugarcane and maize. Rice is grown as *kharif* and *rabi* crop. Rodent damage (Table 1) to rice crop in *kharif* season ranged from 6.6 -15.5% during 2009-10 to 2013-14. Damage to *rabi* rice was 4.1 -16.6% during same period. Average damage was almost similar during both *kharif* (12%) and *rabi* (11.1%) seasons. Damage to sugarcane crop was 13.5% in 2012-13 and 5.5% in 2013-14, whereas, damage to *kharif* maize varied from 1.0-1.5% in the year 2012-13.

Table 1. Rodent damage to field crops in Godavari zone

Year	Month	Crop	Percent damage
2009-10	*Kharif* *Rabi*	Rice	6.6 4.1
2010-11	*Rabi*	Rice	8.7
2011-12	*Kharif* *Rabi*	Rice	15.5 16.6
2012-13	*Kharif* *Rabi*	Rice	12.3 12.9
	Kharif	Sugarcane	13.5
	Kharif	Maize	1.0-1.5
2013-14	*Kharif* *Rabi*	Rice	13.6 10.7
	Kharif	Sugarcane	5.5

Regular monitoring of rodent damage to plantation crops such as coconut revealed rodent damage ranging from 2.1 to 4.8% in the year 2008-09 (Fig. 2) with maximum damage in the month of May. In the year 2012-13 (Fig. 3), damage to coconut ranged from 4.8 to 11.9% with maximum in the month of December, whereas, in the year 2013-14 (Fig. 4), damage to coconut ranged from 5.6 to 8.7% with maximum damage in the month of September. In all the three years surveyed, minimum damage to coconut was found in the month of July. Rodent damage was also monitored regularly to cocoa plantation in the years 2012-13 (Fig. 5) and 2013-14 (Fig. 6). Data revealed rodent damage ranging from 1.7 to 7.3% and 3.0 to 5.6%, respectively in the two years with maximum damage in the months of August and November, respectively. Damage to these two crops was caused mainly by *R. rattus.*

In Rayalaseema zone having scarce rainfall (500-750mm), the major crop grown is groundnut. This crop is grown in both *kharif* and *rabi* seasons. Rodent damage to groundnut crop was observed to be 13.1% in *kharif* season during the year 2010-11. In the year 2011-12, damage in *rabi* season (4.6%) was comparatively lower than that found in *kharif* season (6.1%).

In high altitude zone of Andhra Pradesh having maximum rain fall (above 1400 mm), rodent damage and infestation was recorded in different crops during the 2010-11 (Table 2). Damage was found to be 5.6, 4.2 and 3.6% in rice, cotton and sugarcane crops, respectively. In addition, minor damage (1-2%) was recorded in pulses and jowar. Rodent infestation was high in rice, cotton and sugarcane crops (12-24 live burrows/ha), whereas, in pulses and jowar, live rodent burrows per ha ranged from 8-12.

In north coastal zone having rainfall 1000-1100 mm, rodent damage and infestation was recorded in different crops during the 2011-12. Damage was found to be 3-4% in rice and sugarcane crops and 2% in maize crop, whereas coconut suffered upto 6% rodent damage to nuts. Rodent infestation in the region was, however, low ranging from 2-4 burrows per ha during the year. In Krishna zone having rainfall 800-1100 mm, rodent damage was 5.4% in rice, 1.8% in sugarcane, 2% in maize and 5.3% in coconut crops during the year 2012-13. Rodent burrow count ranged from 2-10.3 per ha in rice, sugarcane and maize crops.

Table 2. Rodent damage to different crops in High altitude zone during 2010-11

Name of the crop	Per cent damage	Burrows/ha
Rice	5.6	18-23
Cotton	4.2	12-24
Sugar cane	3.6	14-20
Pulses	1-2	8-12
Jowar	1-2	8-10

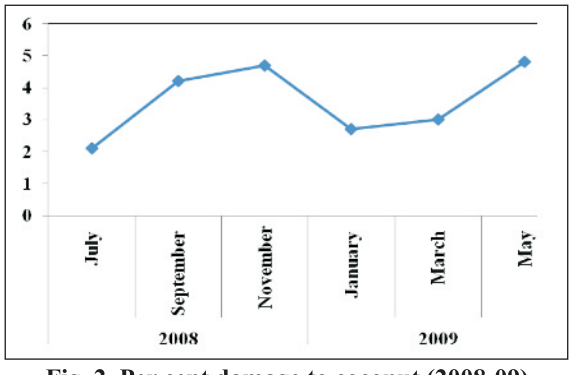


Fig. 2. Per cent damage to coconut (2008-09)

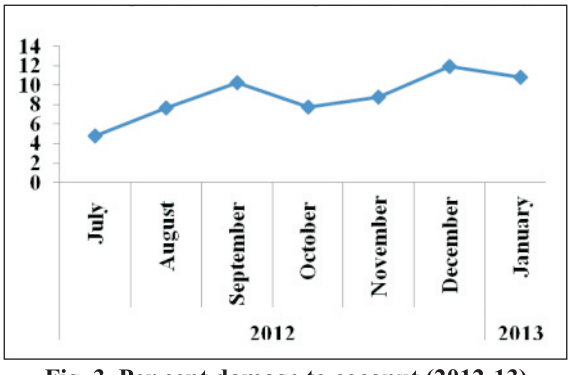


Fig. 3. Per cent damage to coconut (2012-13)

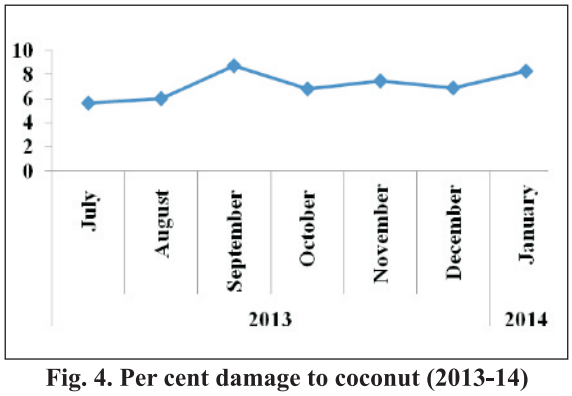


Fig. 4. Per cent damage to coconut (2013-14)

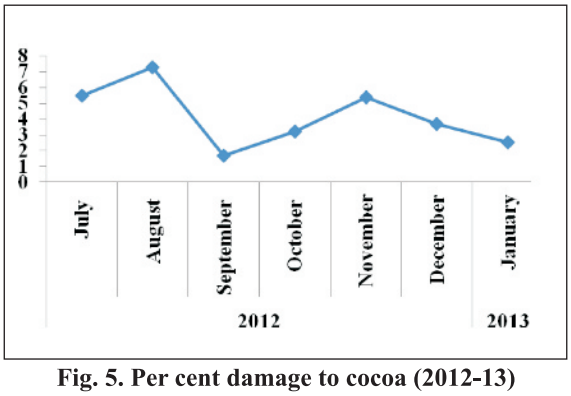


Fig. 5. Per cent damage to cocoa (2012-13)

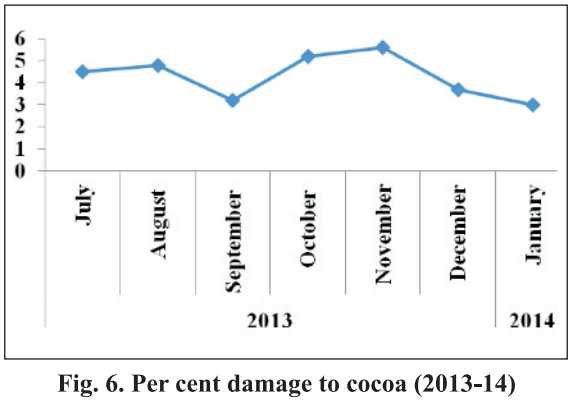


Fig. 6. Per cent damage to cocoa (2013-14)

During 2013-14, rodent damage (Table 3) was 5-8% in rice, 2-5% in maize and 5-9% in sugarcane crops. The damage to coconut and cocoa was 8.5 and 4%, respectively. In addition, rodents also caused 0.5-4.5% loss poultry eggs, 5-8% loss to 30 day old poultry chicks and loss to poultry feed @ 2-10 kg/day/100m^2 floor area. Rodent damage of 2.5 to 5% to food grains was reported in indigenous storage structures.

Table 3. Damage potential of rodents in different crops/commodities in 2013-14

Crops/Commodities	Extent of damage by rodents
Rice	5.0- 8.0%
Maize	2.0-5.0%
Sugar cane	5.0- 9.0%
Coconut	8.5% nut damage
Cocoa	4.0% nut damage
Poultry	0.5-4.5% eggs 5-8% of 30 days old chicks 2-10 kg feed/day/100 m^2 floor area
Stored grains	2.5 -5% (indigenous storage structures)

In general the rodent infestation in east and west Godavari districts in *kharif* and *rabi* seasons during 2015-17 was low to moderate. In West Godavari, incidence was relatively higher over the East Godavari with peak rodent incidence of 37 and 17 burrows/ha during *kharif* season in West and East Godavari, respectively. The rodent infestation was medium and tiller damage was 4.78 and 5.49 percent in *kharif* and below economic threshold level (<4%) in *rabi* season in East and West Godavari districts, respectively (Fig. 7).

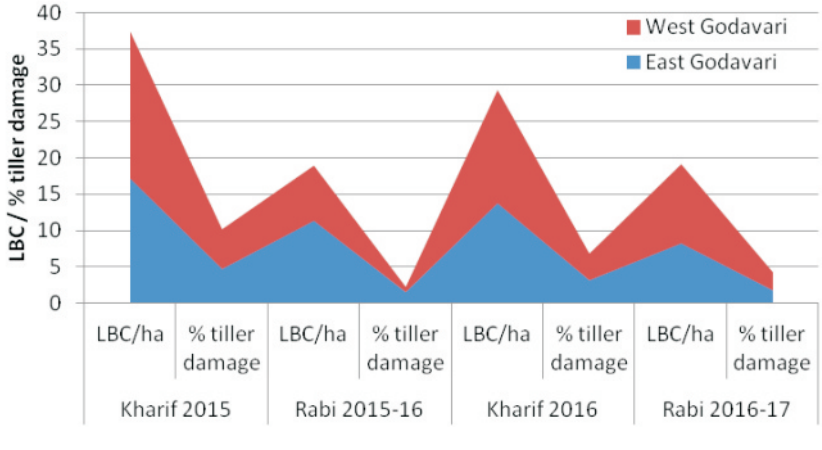


Fig. 7. Rodent infestation in Godavari districts

3. ARUNACHAL PRADESH

Arunachal Pradesh situated in the north-eastern part of India attained its statehood in 1987. The state shares its border with the neighboring countries of Bhutan in the west, China (Tibet) in the north and north-east, Myanmar in the east and south-east and the Indian states of Assam and Nagaland in the south. It stretches from snow-capped mountains in the north to the plains of Brahmaputra valley in the south. Area-wise Arunachal Pradesh is the largest state in the north-east region. It is an ethnic state inhabited by tribal people of diverse culture and lifestyle. The areas around the middle belt of Arunachal Pradesh are cooler, experiencing micro thermal climate. The higher regions of Arunachal Pradesh witness snowfall during the winter. There is alpine climate in the higher altitudes of the state. Arunachal Pradesh experiences heavy rainfall during May to September. The rainfall varies between 800-4500 mm with average rainfall of 3000 mm. Arunachal Pradesh being essentially hilly with deep valley and high mountain peaks traversed by number of rivers and rivulets.

The center of AINP on VPM (Rodent Control) for Arunachal Pradesh is working since 2009-10 at College of Horticulture and Forestry, Pasighat (East Siang Distt) under Central Agricultural University, Imphal. Rodent fauna of Arunachal Pradesh consists of *Rattus rattus, Bandicota bengalensis, R. sikkimensis, Mus cookie nagarum and* Particolored flying squirrel, *Hylopetes alboniger.*

In both the East and West Siang districts, *R. rattus* was reported infesting almost all the crops. *B. bengalensis* was reported from rice, maize, pineapple and cabbage crop fields. In addition, *H. alboniger* was found in pineapple fields. *M. cookie nagarum* was reported from maize crop in East Siang and rice crop in West Siang districts and *R. sikkimensis* was observed in rice, maize, pine apple and french beans in East Siang and in rice crop in West Siang districts (Fig. 8).

Relative abundance of rodent species in different crops in Arunachal Pradesh is shown in Fig. 9. In wetland rice crop, *R. sikkimensis w*as found to be the predominant species, whereas, in *Jhum* rice, maize, cowpea, potato and tomato, *R. rattus* was found to be the predominant species. In crops like pumpkin, cabbage, carrot, radish and french beans, only *R. rattus* was found. In cassava, similar infestation level of *R. sikkimensis*, *R. rattus* and *B. bengalensis* was found. In pineapple crop also similar infestation level of *R. sikkimensis* and *R. rattus* was found.

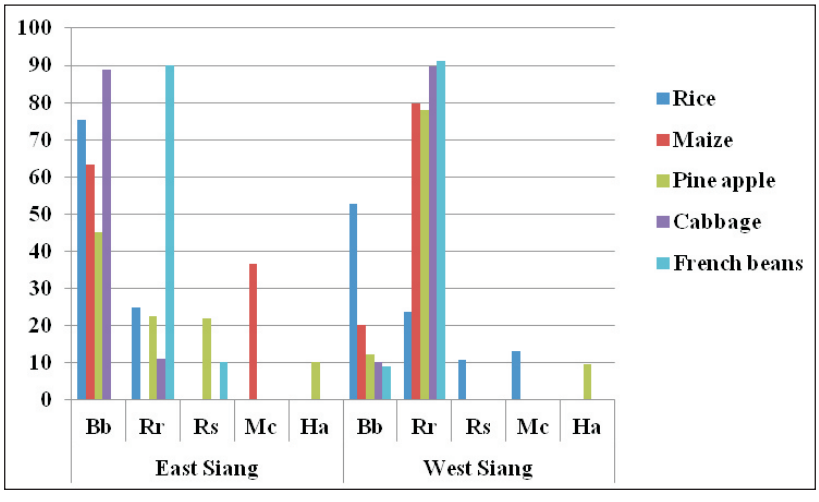


Fig. 8. Rodent species found in different crops in two districts of Arunachal Pradesh

Damage by rodents was recorded in different crops in different districts of Arunachal Pradesh (Fig. 10) from 2009-2017. Damage to wet land and *Jhum* rice crops ranged from 0-24.5% in the years 2009-10 to 2016-17 (Table 4). Damage to sugarcane was 2.8-3.1% in East Siang district. Maize crop suffers up to 12.4% rodent damage in different districts. Rodent damage to cassava roots ranged from 0.7-18.4%. Among pulses, damage to French beans was up to 2.3%. In potato, tomato, cabbage, pumpkin, carrot, cowpea, brinjal and cucurbit crops, rodent damage ranged from 0-2.4%, 0-1.7%, 0.5-1.8%, 1.2-2.2%, 0.5%, 4.3%, 0-0.1% and 0.8-1.1%, respectively. Rodent damage to pineapple fruits varied from 2.3-15.5%.

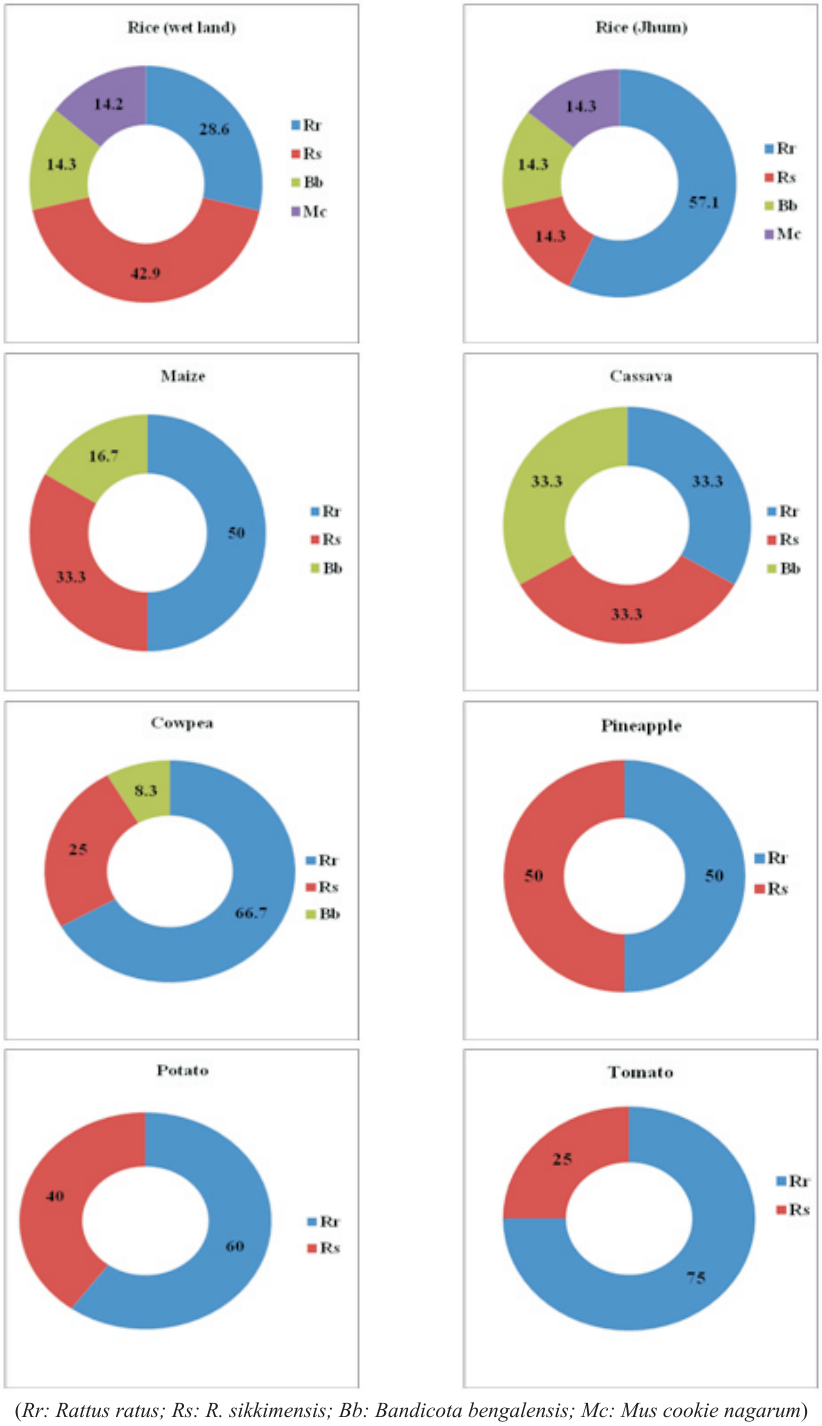
Table 4. Rodent damage to crops in different districts of Arunachal Pradesh

Year	Location	Crop	Damage (%)
2009-10	East Siang district	Rice (wetland)	4.2-16.3
		Rice (*Jhum*)	16.2-24.5
		Sugarcane	2.8-3.1
		Maize	8.0-12.4
		Cassava	8.4-12.8
2010-11	East Siang district	Rice (wetland)	0-8.3
		Rice (*Jhum*)	3.3-8.2
		Maize	0-3.3
		Cassava	0.7-18.4

Year	Location	Crop	Damage (%)
		French bean	0-2.3
		Potato	0-0.5
		Tomato	0-1.7
		Cabbage	0.5-1.8
		Pineapple	7.4-15.5
2011-12	East Siang and West Siang Districts	Rice (wetland)	3.4
		Rice (*Jhum*)	2.9
		Maize	1.9
		Cassava	5.5
		French bean	1.0
		Potato	1.2
		Tomato	0.9
		Cabbage	0.3
		Pumpkin	2.2
		Pineapple	7.7
2012-13	East Siang, West Siang, Lower Dibang valley and Lohit districts	Rice (wetland)	2.2
		Rice (*Jhum*)	2.1
		Maize	7.9
		Cassava	1.6
		French bean	2.1
		Potato	2.4
		Tomato	0.3
		Pumpkin	1.2
		Cabbage	0.6
		Carrot	0.5
		Cowpea	4.3
		Pineapple	2.3
2013-14	East Siang District	Rice (Wetland and *Jhum*)	2.7
		Maize	3.4
		French beans	0.4
		Potato	1.8
		Tomato	0.1

Year	Location	Crop	Damage (%)
		Cabbage	0.02
		Brinjal	0.1
		Cucurbits	1.1
	West Siang District	Rice (Wetland and *Jhum*)	2.1
		Maize	1.9
	Upper Siang District	Rice (Wetland and *Jhum*)	2.0
		Maize	2.0
2015-16	East Siang District	Rice (Wetland and *Jhum*)	1.4-4.3
		Maize	1.8
		French beans	0.3
		Potato	2.1
		Tomato	0.1
		Brinjal	0
		Cucurbits	0.9
	Lohit District	Rice	2.5
		Maize	0.9
2016-17	East Siang District	Rice (Wetland and *Jhum*)	1.8-2.4
		Maize	2.0
		French beans	0.2
		Potato	2.1
		Tomato	0.2
		Brinjal	0.1
		Cucurbits	0.8
	Lohit District	Rice	5.3
		Maize	1.2

Surveillance of rodent pests in wetland rice, *Jhum* rice, maize and pine apple continuously for about one year (2010) in East Siang district of Arunachal Pradesh revealed (Table 5) presence of pregnant females from April to November in both types of rice crops, indicating breeding throughout the year. In maize and pineapple, more number of pregnant females were found in the month of August. During 2015-16 and 2016-17 in rice and maize crops, 12.3-36.1% pregnant and 8.0-33.3% lactating females were trapped (Table 6).



(*Rr: Rattus ratus; Rs: R. sikkimensis; Bb: Bandicota bengalensis; Mc: Mus cookie nagarum*)

Figs. 9. Relative abundance of different rodent species in different crops in Arunachal Pradesh

Table 5. Surveillance of pest rodents in rice and maize crop fields in East Siang district in 2010

Crop/Month	Reproductive status of females (numbers)			
	Sex ratio M:F	NP	P	L
Rice (wet land)				
April	1:1	2	--	--
June	1:0.8	6	2	1
August	1:0.9	8	2	2
September	1:0.9	5	2	--
October	1:1.3	10	2	--
November	1:1	5	3	--
December	1:0.9	8	--	1
Rice (*Jhum*)				
April	1:1.1	6	2	--
June	1:0.8	8	2	--
August	1:0.9	9	3	2
September	1:1.5	7	2	--
October	1:1.1	8	3	--
November	1:0.8	9	2	1
December	1:0.8	7	--	2
Maize				
April	--	--	--	--
June	1:1	2	2	--
August	1:0.7	3	1	--
Pineapple				
April	1:0.7	2	1	-
June	1:1.5	3	2	1
August	1:1.5	12	3	3
October	1:0.7	7	1	--

NP-non pregant, P-pregnant, L-lactating

Table 6. Surveillance of pest rodents in rice and maize crop fields in East Siang district of Arunachal Pradesh in 2015-17

Crop	M:F	NP	P	L
2015-16				
Rice (wetland)	1:1	54.4%	12.3%	33.3%
Rice (*Jhum*)	1: 1.1	56.4%	20.5%	23.1%
Maize	1:1	64.0%	28.0%	8.0%
2016-17				
Rice (wetland)	1:1.1	49.2%	36.1%	14.7%
Rice (*Jhum*)	1:1	43.3%	26.7%	30.0%
Maize	1:1.0	61.9%	23.8%	14.3%

NP-non-pregnant, P-pregnant, L-lactating

The rodent infestation and damage also coincided with the breeding season of rats in different crops (Fig. 10). Higher rodent infestation and damage was generally observed in the month of October in both wet land and *Jhum* rice crops. In maize, pineapple, potato, tomato and cabbage, rodent infestation and damage were high in the month of August. In cassava and french beans, rodent infestation and damage were highest in April and June, respectively.

Survey of rice and maize crops at different locations in East Siang, West Siang and Upper Siang districts of Arunachal Pradesh in the year 2013 revealed (Table 7) almost similar level of rodent infestation in the three districts as indicated by the live burrow counts, trap index

Table 7. Rodent infestation in rice-maize cropping system of Arunachal Pradesh (2013)

District	Crop	No. of live burrows/ha	Trap index	Damage (%)
East Siang	Rice	8.0±2.0	7.4±5.0	2.7±1.7
	Maize	2.9 ±1.2	9.3±4.0	3.4±2.1
West Siang	Rice	6.6±2.3	7.8±5.1	2.1±0.8
	Maize	2.2 ±1.5	5.1±2.5	1.9±0.2
Upper Siang	Rice	7.0 ±2.0	10.0±4.4	2.0±0.8
	Maize	3.7±1.5	7.7±3.8	2.0±0.9

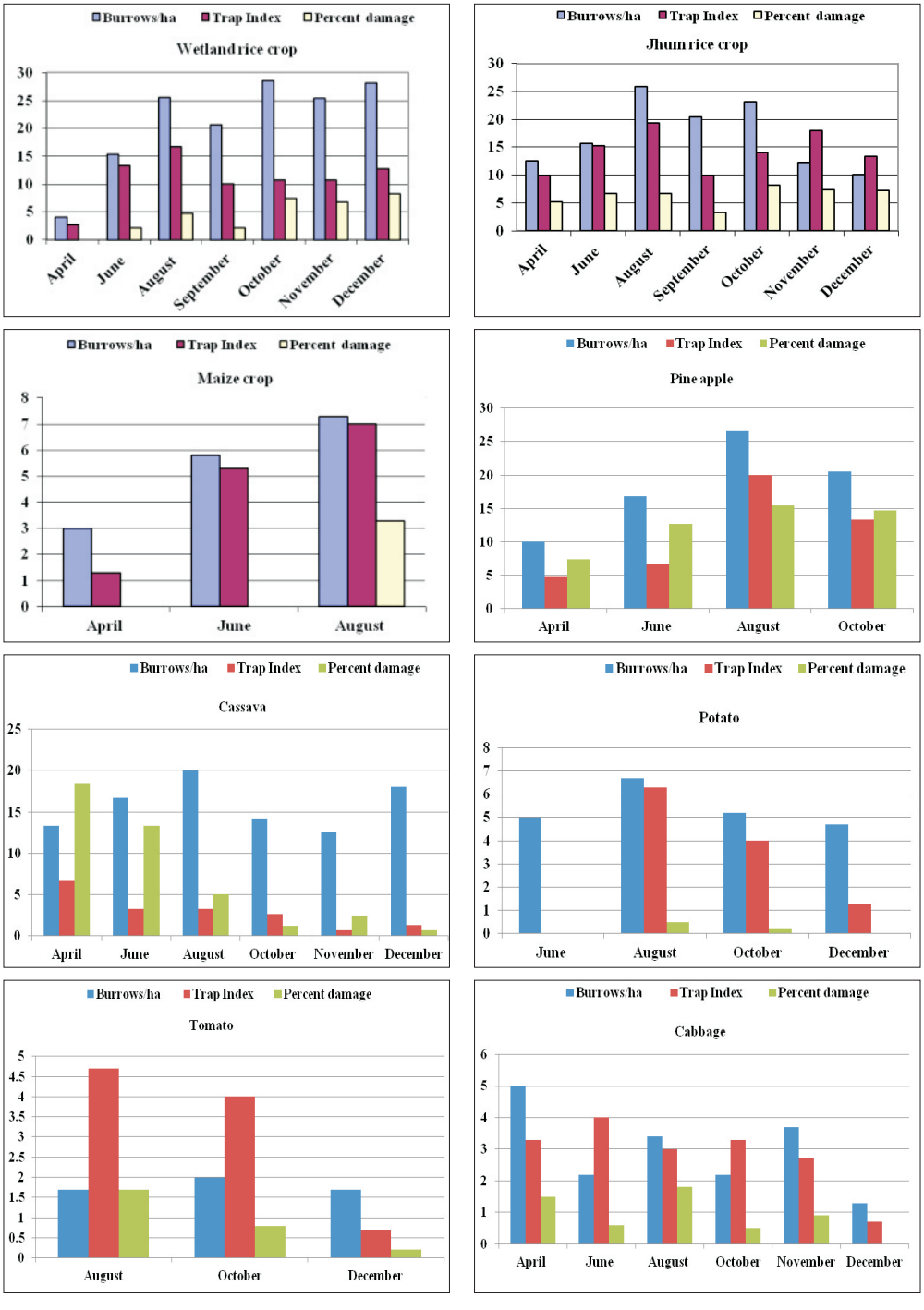


Fig. 10. Surveillance of rodent pests in different crops in East Siang district in Arunachal Pradesh

and damage. In the years 2015-17 also, rodent damage to rice and maize was almost similar to that in 2013 in East Siang district.

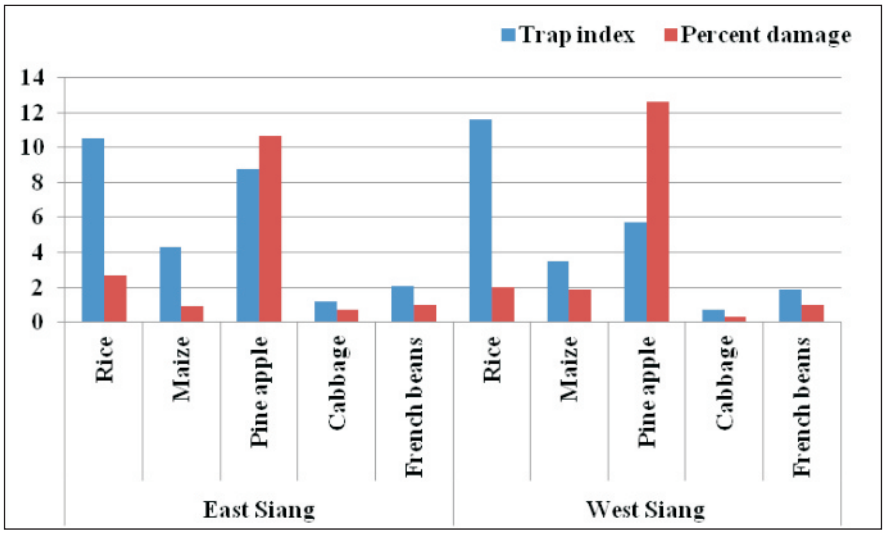


Fig 11. Rodent infestation and damage in in East and West Siang districts in Arunachal Pradesh

In both East Siang and West Siang districts of Arunachal Pradesh, rodent infestation and damage in the year 2013 was comparatively high in rice and pineapple crops as compared to maize, cabbage and french beans (Fig. 11).

4. ASSAM

Based on rainfall, terrain and soil characteristics, Assam is broadly delineated into the six agro-climatic zones, viz., 1. North Bank Plains Zone, 2. Upper Brahmaputra Valley Zone, 3. Central Brahmaputra Valley Zone, 4. Lower Brahmaputra Valley Zone, 5. Barak Valley Zone and 6. Hill Zone.

The centre of AINP on VPM (Rodent Control) for Assam is working at Assam Agricultural University, Jorhat. Information on rodent pest species composition and crop damage in different zones have been generated by the center. In Upper Brahmaputra Valley Zone, the predominant rodent species in rice are *Bandicota bengalensis* (65.49%) followed *Mus booduga* (21.93%) and *Rattus sikkimensis* (12.58%). Larger bandicoot rat, *Bandicota indica* and orange bellied Himalayan squirrel, *Dremomys lokriah* were also recorded in rice fields near forests. In the Central Brahmaputra Valley Zone also, the predominant rodent species was *B. bengalensis* (58.8%) followed by *R. sikkimensis* (29.4%) and *M. booduga* (11.8%). The species composition in rice, in the Lower Brahmaputra Valley Zone comprised of *B. bengalensis* (48.94%), *Rattus nitidus* (26.49%), *R. sikkimensis* (17.43%) and *M. booduga* (7.14%).

Overall, *B. bengalensis* was the predominant species found in all the habitats i.e. both in crop fields and premises. Other species varied from area to area. Species composition in various habitats are depicted in Fig 12.

Rodent species found in houses, granaries, crop fields and forest near bamboo flowering areas were *R. nitidus, R. sikkimensis,* Himalayan white bellied rat, *Niviventer niviventer,* Himalayan chestnut rat, *Niviventer fulvescens, B. bengalensis, B. indica, R.rattus* and *M. musculus.* Survey of different storage structures in the year 2012-13 revealed the occurrence of *M. musculus, R. rattus* and *B. bengalensis* in indoor stores causing 20-46.7% damage to bags in addition to structural damage and spillage. Rodent species found in outdoor stores were *B. bengalensis, B. indica* and *D. lokriah.* Rodent burrows (2.3-3.1 per structure) were found in the floor area.

Assessment of rodent damage in rice ecosystems of seven villages of Jorhat and Golaghat districts of Assam revealed that *Bao* rice suffered the maximum rodent damage (16.7%) followed by *Sali* (10%) and *Ahu* rice (5.6%) and the lowest damage of 4% was recorded in *Boro* rice.

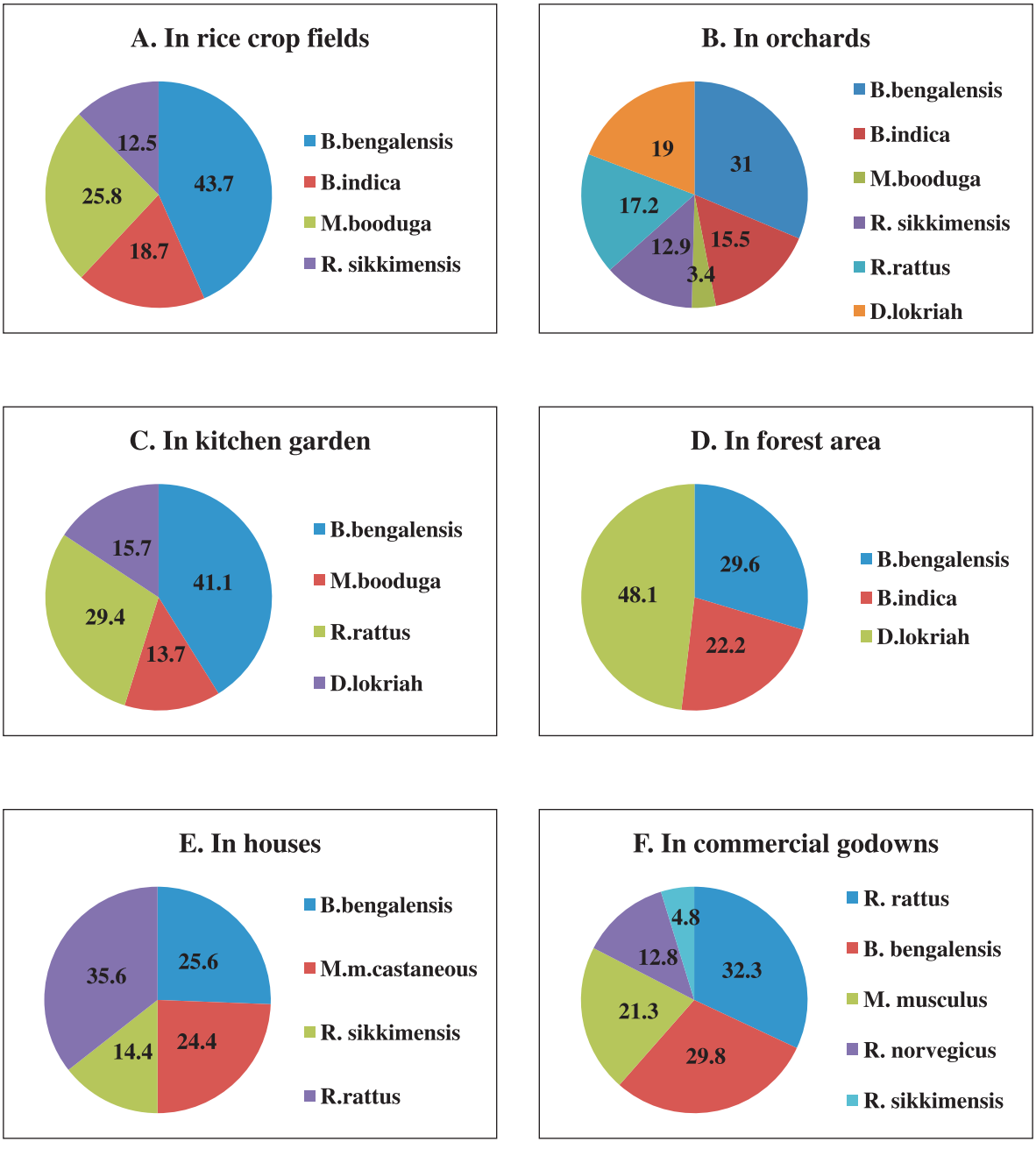


Fig. 12. Rodent pest species composition in different habitats in Assam

Damage in different agro climatic zones of Assam (Table 8) also revealed maximum rodent damage to *Bao* rice (11.9-17.6%) and minimum in *Boro* rice (2-5%) during the year 2009-10 in Upper Brahmaputra Valley Zone. In addition to rice, maximum damage was observed in areca nut (40.8%) and Pummelo (42.1%) fruits in this zone. During 2011-12, rodent damage varied from 10.1-16.4% in crops like pumpkin, potato, pea and beetroot. In Lower Brahmaputra Valley Zone during both *kharif* and *rabi* seasons (2010-11) crops such as toria, potato, sugarcane, pumpkin, wheat, buck wheat, summer rice, niger, sweet potato and beet root experienced 7.6-14% rodent damage. Rodent abundance in general was found to vary from 14.4-26.6 live burrows per ha. In the North Bank Pain Zone during the year 2012-13, rodent damage was 14.2% in sugarcane, 14.6% in potato and 14% in pumpkin. Maximum damage was observed in potato crop and minimum to knolkhol crop. Rodent abundance ranged from 5.7-22.6 live burrows per ha.

Table 8. Rodent damage to field crops in different agro-climatic zones of Assam

Year	Location	Month/season	Crop	Damage (%)	Live burrow count(No./ha)
2009-10	UBVZ	*Kharif*	Rice	9.9-10.8	-
		Ahu/summer	Rice	3.6-7.5	-
		Boro	Rice	2.0-5.0	-
		Bao	Rice	11.9-17.6	-
		Kharif/Rabi	Araca nut	40.8	-
		Kharif/Rabi	Pummelo	42.1	-
2011-12	UBVZ	*Rabi*	Pumpkin	13.0	-
			Potato	16.3	-
			Pea	16.4	-
			Beet	10.1	-
2010-11	LBVZ	*Kharif/Rabi*	Toria	10.2	20.6
			Potato	9.2	16.6
			Sugarcane	14.0	22.4
			Pumpkin	8.2	14.4
			Wheat	9.0	20.2
			Buck wheat	12.6	23.3
			Summer rice	10.6	20.7
			Niger	12.8	26.6
			Sweet potato	12.2	20.6
			Beet	7.6	16.8

Year	Location	Month/season	Crop	Damage (%)	Live burrow count(No./ha)
2012-13	NBPZ	*Kharif/Rabi*	Potato	14.6	16.6
			Pumpkin	14.0	14.0
			Pea	12.7	12.7
			Brinjal	5.1	7.9
			Carrot	7.80	7.8
			Beet	12.7	11.6
			Sugarcane	14.2	22.6
			Tomato	7.6	6.2
			Radish	4.2	5.7
			Knolkhol	4.1	6.1

UBVZ: Upper Brahmaputra Valley Zone, LBVZ: Lower Brahmaputra Valley Zone, NBPZ: North Bank Plain Zone

During the years, 2010-12 and 2015-17, the incidence of *B. bengalensis* as well as damage in rice crop at different crop stages (Table 9) was maximum at ripening stage followed by dough, flowering, panicle initiation and maximum tillering stage.

In vegetable crops, the incidence of *B. bengalensis* during 2010-12 and 2015-17 was (Table 10).maximum in pea, potato, pumpkin and beet root crops (live burrow counts: 10.2-36.7 per ha). Rodent damage in these crops varied from 3.3 to 16.4%. Live burrow count and trap indices in other vegetable crops viz., brinjal, tomato, carrot, cauliflower, cabbage and knolkhol varied from 3.5-24.7 and 2-3.7 registering a damage of 1.9 to 6.2%.

Table 9. Incidence of *B. bengalensis* in rice crop during 2010-12 and 2015-17

Crop growth stages	Live burrow count (No./ha)	Trap index	Damage (%)
Maximum tillering	7.9-10.6	2.6-3.3	1.9-2.7
Panicle initiation	15.9-16.4	4.3-6.1	2.5-9.0
Flowering	23.6-32.7	6.1-8.7	4.4-12.5
Dough	25.5-36.1	6.8-10.7	4.7-14.4
Ripening	33.7-42.7	6.6-12.1	6.6-16.3

Table 10. Incidence of *B. bengalensis* in vegetable crops during 2010-12 and 2015-17

Crop (vegetables)	Live burrow count (No./ha)	Trap index	Damage (%)
Cauliflower	6.1	3.2	3.7
Brinjal	5.9-22.1	2.1-2.8	3.1-4.9
Pumpkin	11.8-36.7	4.5-9.5	7.7-13.0
Potato	14.4-31.8	3.6-10.6	6.7-16.3
Pea	17.2-28.8	3.3-9.9	6.1-16.4
Cabbage	4.6-24.1	2.1-3.7	1.9-6.2
Carrot	6.3-24.7	2.0-2.7	3.2-5.7
Knolkhol	3.5	2.2	3.8
Tomato	4.7-16.7	2.7-3.7	3.2-6.2
Beet	10.2-28.9	3.2-8.6	3.3-10.1

Survey in rice-toria cropping system in the years 2013-14 and 2015-17 revealed maximum rodent damage at ripening stage (16.7%) followed by milky grain stage (12%) and maximum tillering stage (3.3%) of rice crop. Live burrow count/ ha and trap indices varied from 10.6-42.7 and 2.6-11.1, respectively at maximum tillering, milky grain and ripening stages. In toria crop, maximum damage was reported at pod formation stage (10.2%) followed by flowering (4.7%) and vegetative (2.1%) stages (Table 11).

Table 11. Incidence of rodent pests in rice-toria cropping system (2013-14 and 2015-17)

Crop	Crop stage	Live burrow count (No. /ha)	Trap index	Damage (%)
Rice	Maximum tillering	10.6	2.6-4.6	1.9-3.3
	Milky grain	18.7-32.7	6.1-8.3	4.4-12.0
	Ripening	34.4-42.7	6.6-11.1	6.6-16.7
Toria	Vegetative	10.4-16.6	1.9-6.6	1.2-2.1
	Flowering	14.8-20.2	2.2-10.4	2.0-4.7
	Pod formation	16.6-26.6	2.3-12.7	2.3-10.2

Rice-pulse cropping system during 2013-14 (Table 12) also revealed maximum rodent damage at ripening stage (20.7%) followed by milky grain stage (12.4%) and maximum tillering stage (2.9%). In pea crop, maximum damage was reported at pod formation stage (12.7%) followed by flowering (4.9%) stage.

Table 12. Incidence of rodent pests in rice-pulse cropping system (2013-14)

Crop	Crop growth stages	Live burrow count (No. /ha)	Trap index	Damage (%)
Rice	Maximum tillering	6.2	2.4	2.9
	Milky grain	20.2	6.6	12.4
	Ripening	33.3	16.3	20.7
Pea	Vegetative	--	--	--
	Flowering	8.6	3.3	4.9
	Pod formation	22.8	8.1	12.7

Similarly in pulse-toria cropping system in the year 2013-14, maximum rodent damage was observed at pod formation/ripening stage (8.3%) followed by flowering stage (3.9%) of black gram crop. In toria crop, maximum damage was reported at pod formation stage (8.2%) followed by flowering (3.5%) and vegetative (2.1%) stages.

5. JAMMU AND KASHMIR

Ladakh region, situated in the state of Jammu & Kashmir, comes under the Biogeographic Zone 1A - the Trans Himalayas. This zone covers more than 92000 sq km geographical area of the State. Being a high altitude cold arid region, it experiences harsh climatic conditions which include extreme low temperature and very low rainfall leading to poor environmental productivity. District Leh is situated roughly between 32° to 36° N latitude and 75° to 80° E longitude and altitude ranging between 2,300-5,000 m. The district with an area of 45,100 sq km is the second largest district in the country after Kutch (Gujrat). It is bounded by Gilgit in the west and China in the north and eastern part and Lahaul and Spiti of Himachal Pardesh in the south east. Topographically, the whole district is mountainous with three parallel ranges, the Zanskar, the Ladakh and the Karakoram ranges of the Himalayas. Between these ranges, the Shayok, Indus and Zanskar rivers flow and most of the population lives in valleys of these rivers.

Agriculture is the backbone of the economy of Ladakh. About 70 percent population is engaged in agriculture and animal husbandry. *Grim* (Naked Barley) is major food grain crop in the district. Wheat, pulses, oil seeds and other millets are also grown, besides alfa-alfa as fodder. Vegetable cultivation, especially under protective cultivation, though in limited scale has also gained importance in recent years. The vegetables grown are mainly brinjal, capsicum, cucurbits, cabbage, cauliflower and cherry. Likewise, apple and apricot are major fruit crops.

ICAR-CAZRI, Jodhpur center of AINP on Vertebrate pest management undertook a detailed survey of rodent fauna in Leh-Ladakh region during 2014-16, wherein occurrence of five species were reported from crop fields, residential areas; godowns and storage and grasslands and barren lands at various altitudes up to 5000 m above mean sea level (amsl).

Survey of rodents in crop fields, fallow lands, greenhouses, field storage, godowns etc. located at various altitudes in the Leh region revealed the existence of Indian field mouse, *Mus booduga* and Turkish rat, *Rattus turkestanicus.* Field mouse was trapped from crop fields, whereas the Turkish rat was trapped from stores and residential premises. At higher altitudes, activities of marmots (*Marmota himalayana*) were observed at foot hills and grasslands (Table 13). The population of marmots was maximum (55.2%) followed by field mouse (24.1%) and Turkish rat (20.7%). In overall, rodent infestation was more in godowns and shops (1.3%) than field storages (1%).

Analysis of altitudinal distribution revealed *M. booduga* inhabiting field areas and *R. turkestanicus* inhabiting indoor areas at an altitude of 3350-3650m; *M. himalayana* and the vole, *Pitymys leucurus* inhabiting barren lands and grasslands at an altitude of 4250-5200 m. A new species of *Rattus* (to be identified) was also recorded at an altitude of 3658 m at outskirts of Leh city near Saboo village.

An overall spike damage of upto 2% was observed in barley and wheat crops due to *M. booduga* and a burrow density of 3-20 live burrows/m^2 of voles (*Pitymus leucurus*) was observed at higher altitudes (4267 to 4877 m) in grasslands.

Table 13. Habitat wise rodent diversity in Leh-Ladakh (J&K)

Habitat	Species trapped	Total No. trapped/ observed	Trap index (rodents/trap/day)
Horticulture plantation and crop fields			
Crop fields	*Mus booduga*	05	0.08
Fallow land in city area	*Mus booduga*	01	0.03
Horticulture plantation	*Rattus turkestanicus*	01	0.03
	Mus booduga	01	0.03
Storage and residential premises			
a. Godowns & shops	*Rattus turkestanicus*	07	0.12
	Mus booduga	06	0.10
b. Field stores	*Mus booduga*	01	0.03
c. Office premises of CEC	*Rattus turkestanicus*	04	0.07
Grassland/barren land on foot hills	*Marmota himalayana*	32 (Observed)	-
	Pitymus leucures	06	-

6. KARNATAKA

Karnataka is divided into ten agro-climatic zones taking into consideration the rainfall pattern-quantum and distribution, soil types, texture, topography major crops and type of vegetation. The zones are 1. North Eastern Transition Zone, 2. North Eastern dry Zone, 3. Northern Dry zone, 4. Central Dry Zone, 5. Eastern dry zone, 6. Southern dry zone, 7. Southern Transition Zone, 8. Northern transition zone, 9. Hilly zone and 10. Coastal Zone. Agricultural production in the state is spread over three seasons namely *kharif* (July to October), *rabi* (October to March) and summer. These seasons account for nearly 70, 22 and 8% of annual food grain production, respectively. Crops like, pigeon pea, bajra, jowar, minor millets, sesame, castor and niger are purely *kharif* crops. Wheat, *rabi* jowar and safflower are cultivated in *rabi* season. Cereal crops like paddy, jowar, ragi and maize; pulses and oilseed crops such as groundnut and sunflower can be grown in all three seasons. The *kharif* crops are cultivated in all the agroclimatic zones, whereas, the *rabi* crops are mostly cultivated in northeastern dry and northern dry zones.

The center of AINP on VPM for Karnataka state is working at University of Agricultural Sciences, GKVK, Bengaluru. Regular survey of rice crop grown in *kharif* season (Table 14) revealed rodent damage at all the crop stages such as at nursery stage (2.3%), at the time of sowing/transplanting (2.7-4.8%), at tillering stage (2.2-3.5%), at ear head formation stages (2.5-7.5%) and at harvesting stage (3.3-7.3%). Yield loss ranged from 186-250 kg/ha. Rodent fauna consisted of predominance of *Mus booduga,* followed by *Bandicota bengalensis, Tatera indica, Millardia meltada* and *M. musculus.* In the years 2015-17, rodent damage to rice ranged from 4.6 to 8.9% with *M. booduga* to be the predominant species followed by *M. meltada* and *B. bengalensis.*

Extent of rodent damage to other cereal and vegetable crops was also reported at all the from sowing to harvesting stage. Maize grown in summer season, rodent damage was 1-2.3% at the time of sowing, 1-3.5% at tillering stage, 2.7% at cob formation stage and 4.2% at the time of harvesting. In this crop, *T. indica* was the predominant species followed by *B. bengalensis* and *M. booduga*. In wheat, rodent damage was 3.6, 4.6 and 5.6% at sowing, ear head formation and maturity stages, respectively. Rodent fauna consisted of *B. bengalensis* followed by *M. booduga* and *T. indica*. (Table 15).

Table 14. Rodent fauna and damage in rice at different stages in Karnataka

Year	Location	Crop stage	Damage (%)	Rodent species	Yield loss (kg/ha)
2009-10	Mandya	Tillering Ear head formation Harvesting	3.5 5.6 6.6	*Bb>Mb>Ti*	280
	Sulivara (Ramanagara)	Tillering Ear head formation Harvesting	3.0 4.0 4.0	*Bb>Mb>Ti*	220 to 250
	Sirsi	Tillering Ear head formation Harvesting	2.2 6.3 7.2	*Mb>Bb*	-
2010-11	Kumta	Nursery Ear head formation Harvesting	2.3 7.5 3.3	*Mb>Bb>Mme*	186
2011-12	Kumta	Sowing/transplanting Ear head formation Harvesting	2.8 2.5 6.5	*Mb>Bb>Mm*	-
2012-13	Sirsi	Sowing/transplanting Tillering Ear head formation Harvesting	4.8 2.7 3.7 7.2	*Mb>Bb>Mme*	220
2013-14	Sirsi	Sowing/transplanting Ear head formation Harvesting	2.7 4.6 7.3	*Mb>Bb>Mme*	-

Bb: B. bengalensis;Mb: M. booduga; Ti: T. indica; Mme: M. meltada

Rodent damage to other crops viz., sorghum, ragi, potato, cabbage etc at different crop growth stages is briefed in Table 15. The species involved comprised of *B. bengalensis*, *M. booduga, T. indica, M. meltada* and *Mus platythrix* in varying proportions. In sorghum-Bengal gram cropping system, the predominant species recorded during the years 2015-17 were *B. bengalensis* followed by *M. platythtix, M. meltada* and *T. indica.* The breeding activity was noticed throughout the year. In ragi-cow pea cropping system, during the years 2015-17, peak incidence of 7.3% was recorded in ragi while it was 6.3% in cowpea.

In groundnut crop (Table 16) 2.8-6.8% damage was noticed at the time of sowing, 0.9-2.8% at vegetative stage, 2.7-4.2% at peg formation stage, 3.2-4.9% at pod formation stage and 5.2-8.6% at the time of harvesting. Yield loss ranged from 208-257 kg/ha. In this crop, *T. indica* and *B. bengalensis* were found to be the predominant species.

Table 15. Rodent fauna and damage in other cereal and vegetable crops at different growth stages in Karnataka

Crop	Year	Location	Period	Crop stage	Damage (%)	Rodent fauna
Maize	2009-10	Mandya	Jul-Nov	Sowing Tillering Harvesting	1.0 3.5 4.2	*Ti >Mb>Bb*
	2010-11	Shimoga	Jun - Oct	Sowing Vegetative stage Cob formation	2.3 1.0 2.7	*Ti>Bb*
Wheat	2009-10	Dharwad	Jul-Nov	Sowing Ear head formation Maturity	3.6 4.6 5.6	*Bb>Mb>Ti*
Sorghum	2009-10	Bidar	Jun - Oct	Sowing Milky grain Harvesting	1.5 4.7 5.6	*Mb>Bb*
	2011-12	Shimoga	Oct-Dec	Sowing Harvesting	3.8 1.9	*Bb>Ti*
	2012-13	Gulbarga	Jul-Nov	Sowing Tillering Milky grain	4.7 1.8 5.8	*Bb>Mb*
	2013-14	Gulbarga	Jun-Oct	Sowing Tillering Harvesting	3.7 1.8 5.7	*Ti>Bb>Mme*
Ragi	2009-10	Mandya	Nov-Dec	Tillering Harvesting	4.0 4.5	*Ti >Mb>Bb*
	2012-13	Chamaraja nagar	Aug-Nov	Sowing Tillering Ear head formation Harvesting	1.7 1.9 3.0 7.2	*Bb>Ti>Mb*
	2013-14	Chamaraja nagar	July-Oct	Sowing Tillering Milky grain Harvesting	1.6 1.7 3.9 6.1	*Bb>Ti>Mme> Mp*

Crop	Year	Location	Period	Crop stage	Damage (%)	Rodent fauna
Potato	2011-12	Chikkaballapura	Oct	Harvesting	5.2	*Bb>Mb*
	2013-14	Chikkaballapura	Apr-May	Harvesting	7.3	*Bb>Mme*
Cabbage	2011-12	Chikkaballapura	Oct	Harvesting	5.6	*Bb>Mb*
	2013-14	Chikkaballapura	Apr-May	Head formation	2.5	*Bb>Mme*

Bb: B. bengalensis;Mb: M. booduga; Ti: T. indica; Mme: M. meltada

Table 16. Rodent species and damage in groundnut crop at different stages in Karnataka

Year	Location	Period	Crop stage	Damage (%)	Rodent fauna
2009-10	Chikkaballapura	Aug - Oct	Peg formation Harvesting	4.2 5.2	*Ti >Mb >Bb >Mp*
2010-11	Srirampura (Chikkaballapura)	Sep-Nov	Veg. stage Harvesting	2.8 5.4	*Ti>Bb>Mb*
	Kumta	Apr-May	Pod formation Harvesting	4.9 6.3	*Mb>Bb>Mme*
2011-12	Srirampura	Oct-Nov	Sowing Veg. stage Pod formation Harvesting	3.6 1.3 5.3 8.6	*Ti>Mb>Bb*
2012-13	Chamarajanagar	Aug-Nov	Sowing Peg formation Pod formation Harvesting	6.4 2.7 3.2 5.8	*Bb=Ti*
2013-14	Chamarajanagar	Aug-Nov	Sowing Veg. stage Pod formation Harvesting	6.8 2.3 4.1 6.3	*Bb>Ti>Mp>Mme*

Bb: B. bengalensis;Mb: M. booduga; Ti: T. indica; Mme: M. meltada

In sesame crop rodent damage was between 1.2-5.2% at vegetative stage, 7.3-8.2% at pod formation stage and 7.3-9.6% at harvesting stage. There was predominance of *T. indica* followed by *B. bengalensis* and *M. booduga*. Likewise cardamom crop suffered rodent damage (1.5-12.4%) at capsule formation stage only mainly by squirrels, *Funnambulus palmarum.* Yield loss ranged from 208-257 kg/ha. (Table 17).

Table 17. Rodent fauna and damage in cardamom and sesame crops at different stages in Karnataka

Crop	Year	Location	Period	Crop stage	Damage (%)	Rodent fauna
Sesame	2009-10	Ramanagara	May-Jul	Veg. stage Pod formation Harvesting	2.1 8.2 7.3	*Ti >Mb>Bb*
	2010-11 / 2011-12	Srirampura	Apr-Jun	Veg. stage Pod formation	1.2/ 5.2 7.4/7.3	*Ti>Bb*
Cardamom	2009-10	Sirsi	Aug-Apr	Capsule formation	1.5-5.0	*Fp>Bb*
		Mudigere	Aug-Jan	Capsule formation	2.5-6.0	*Fp>Bb>Mb*
	2010-11	Mudigere	Jul-Dec	Capsule formation	2.6-12.4	*Fp>Rr>Bb*
	2011-12	Mudigere	Harvesting	Capsule formation	2.1-8.1	*Fp>Rr*

Bb: B. bengalensis; Mb: M. booduga; Ti: T. indica; Fp: F. palmarum

Pulse crops also suffered rodent damage at all stages of crop growth to the extent of 1.6-3.8% (red gram), 2.7-6.3% (Bengal gram), 2.3-6.8% (soybean) and 3.1-6.5% (cowpea). *B. bengalensis* was the predominant rodent pest in these crops. Other species included *T. indica, M. booduga* and *M. meltada*. Crop stage wise damage is presented in Table 18.

Rodent damage to plantation crops, like cashew nut, coffee and coconut was also assessed. Cashew crop suffers rodent infestation from nursery stage resulting into a damage of 3.0-4.5 % which increased to 4.7-6.3% at inflorescence stages. The species associated with cashew plantations are *F. palmarum, T. indica, B. bengalensis* and *M. booduga.* In coffee plantations rodents (*F. palmarum*, *R. rattus* and *B. bengalensis)* caused, 6-7% damage. In

Table 18. Rodent fauna and damage in pulses at different crop stages in Karnataka

Crop	Year	Period	Location	Crop stage	Damage (%)	Rodent fauna
Red gram	2009-10	Aug-Dec	Sulivara	Seedling Pod formation Harvesting	3.0 5.0 4.0	*Ti >Mb>Bb*
	2013-14	Jul-Dec	Gulbarga	Seedling Tillering Pod formation Harvesting	2.8 1.6 5.7 3.8	*Bb>Mme> Ti*
Bengal gram	2012-13	Oct-Dec	Bidar	Germination Pod formation harvesting	5.1 2.7 6.3	*Bb>Ti*
	2013-14	Oct-Dec	Bidar	Germination Pod formation Harvesting	4.6 5.4 6.1	*Bb>Mme*
Soybean	2009-10	Sep-Oct	Bidar	Vegetative stage Pod formation Harvesting	6.8 2.3 2.8	*Bb >Mb>Ti*
	2011-12	Oct	Chikkaballapura	Pod formation	6.1	*Bb>Mb>Ti*
	2012-13	Aug-Sep	Bidar	Sowing Vegetative stage Harvesting	2.0 3.1 1.8	*Bb>Mb> Mme*
	2013-14	Jun-Sept	Bidar	Sowing Pod formation Harvesting	2.7 5.6 5.6	*Bb>Mme> Ti*
Cowpea	2009-10	Sep- Oct	Bidar	Pod formation Harvesting	6.5 7.3	*Bb >Mb> Ti*
	2012-13	Feb-Mar	Sirsi	Sowing Vegetative stage	3.1 4.3	*Bb>Mb*
	2013-14	Apr-May	Sirsi	Sowing Vegetative stage Harvesting	3.1 4.3 5.8	*Mb>Bb> Mme*

Bb: B. bengalensis;Mb: M. booduga; Ti: T. indica; Mme: M. meltada

coconut, rodent damage to nuts was observed throughout the year, highest being during summers (5.9-14.8%) followed by 3-13.2% in winter season. Most of the damage was caused by *F. palmarum* and *R. rattus*. Among fruit crops, grapes and pine apple experienced 6.1-6.4% and 2.3-5.8% fruit damage by rodents (Table 19).

Table 19. Rodent fauna and damage in plantation and fruit crops at different stages in Karnataka

Crop	Year	Location	Period	Crop stage/ season	Damage (%)	Rodent fauna
Cashew nut	2009-10	Chintamani (Kolar)	Throughout the year	Nursery Inflorescence	3.0 -4.5 4.7-6.3	*Ti >Mb>Bb*
	2010-11	Kumta	Apr-May	Nursery Inflorescence	1.1-3.8 3.2	*Fp>Bb*
Coffee	2009-10	Coorg	Oct-Nov	Berry formation Ripening	6.0 7.0	*Fp>Rr>Bb*
Coconut	2010-11	Kumta	Throughout the year	Summer *Kharif* Winter	13.6 2.7 4.8	*Fp>Rr*
	2011-12	Kumta	Throughout the year	Summer *Kharif* Winter	9.4-12.8 2.1-2.8 3.5-7.8	*Fp>Rr>Bb*
	2012-13	Kumta	Throughout the year	Summer *Kharif* Winter	5.9-14.8 1.6-2.1 3.0-4.7	*Fp>Rr*
	2013-14	Kumta	Throughout the year	Winter	6.5-13.2	*Fp>Rr>Bb*
Grape	2010-11	Chikkaballapura	Apr-May	Inflorescence/ fruit formation	6.4	*Fp>Bb*
	2013-14	Chikkaballapura	Apr-May	Fruit formation	6.1	*Fp>Bb*
Pineapple	2012-13	Sirsi	Feb-Apr	Fruit formation	2.3-4.7	*Ti>Bb>Mb*
	2013-14	Sirsi	Jan-Apr	Fruit formation	2.8-5.8	*Bb>Mb*

Bb: B. bengalensis, Mb: M. booduga, Ti: T. indica, Mp: M. platythrix; Rr- R. rattus, Fp: F. palmarum, Mme- M. meltada

7. ODISHA

Odisha state comprised of 10 agro climatic zones viz., 1. North Western Plateau, 2. North Central Plateau, 3. North Eastern Coastal Plain, 4. East and South Eastern Coastal Plain, 5. North Eastern Ghats, 6. Eastern Ghat Highland, 7. South Eastern Ghat, 8. Western Undulating Zone, 9. Western Central Table Land and 10. Mid Central Table Land. The State covers 47% high land, 28% medium land and 25% low land out of 90.80 lakh hectares of cultivated land. The main cropping pattern followed by the farmers are Rice-Rice-fallow, Rice-Vegetables-fallow and Rice-Pulses-fallow where rice is grown in 42.66 lakh ha, Pulses in 20.80 lakh ha and vegetables in 6.98 lakh ha.

Center of AINP on Vertebrate Pest Management (Rodent Control) was initiated in the State at Orissa University of Agriculture and Technology, Bhubaneswar during 2014-15. Survey conducted during 2015-16 in Jagatsingpur and Kendrapada districts revealed a rodent species composition of *Bandicota bengalensis* (55%) > *Mus booduga* (19.6%) > *Rattus rattus* (16.1%) > *Millardia meltada* (7.15%) > *B. indica* (2.1%) in rice fields. Highest rodent burrow density was found at harvesting stage (41.4/ha), followed by ripening (30.6/ha), milking (18.9/ha) and max-tillering (5.2/ha) stage. Maximum rodent damage in terms of percent cut tiller was also recorded at harvesting stage (12.9%) followed by ripening (9.1%), milking (5.5%) and max-tillering (0.1%) with an average of 6.9% tiller damage. The rodent infestation (LBC/ha) in sugarcane was maximum at cane formation stage (39-41) followed by cane binding (17.2) and cane maturity stage (2.5-4.8) with an average of 19.6 -23.7 LBC/ha during 2015-16 and 2016-17. Rodent damage to cane was also maximum in cane formation stage (25.2%).

In vegetable crops rodent pest composition was *B. bengalensis* > *M. booduga* > -*R. rattus* > *M. meltada*> *B. indica.* However the former two species were the dominant ones. Rodent density (LBC/ha) in different vegetables during 2015-16 recorded maximum in tomato (38.4) followed by potato (17.2), brinjal (16.3) and cauliflower (12.9). The damage in vegetable during 2015-16 was up to 4.2% with an overall mean of 1.65% and maximum damage was also found in tomato (3.75%). During 2016-17 also rodent damage was maximum in tomato (6.8%) followed by pumpkin (4.05%), potato (2.4%) and cucumber & cauliflower (1.7%). Cocoanut orchards harbored only *R. rattus* (100%).whereas in other crops it was ranging from 5.7% to 44.21% followed by *M. meltada*, *M. booduga*, *B. indica.* Maximum population of rodent was found in pineapple at ripening stage (55.2/ha) having damage of 33.1% followed by groundnut at pod maturity stage (37.8/ha) with damage of 7.6%. Other crops like green gram, black gram, toria, maize, banana suffered rodent damage from 0.8% to 8.1%.

8. PUNJAB

The state of Punjab forms a part of Indo-Gangetic alluvial plain and is composed of sediments of Shiwalik Hills and Himalayas brought down and laid by Indus rivers system. The climate of Punjab is dominantly sub-tropical and monsoon type. The mean annual rainfall varies from 300-1200 mm.

Punjab farmers, once at the center stage of green revolution, are facing serious problems of sustaining agricultural productivity because of declining water table and overall resource degradation (soil and water quality) in the central rice-wheat cropping zone; brackish ground water in the canal irrigated southwestern zone, the cotton-wheat belt and problem of recurrent droughts in the ecologically fragile Kandi region. During the course of time, due to intensification of agriculture, the cropping pattern of the state has changed drastically. The whole state is progressing towards a rice-wheat mono cropping system from the multi crop husbandry practices. As rice is a high water demanding crop, the effect is visible on the water balance in different districts of the state. Water logging and secondary salinity are the other consequences of indiscriminate use of good quality and marginal quality waters for irrigation. Besides several biotic factors including rodent pests are resulting into decreased crop productivity.

The center of AINP on VPM (Rodent Control) for Punjab state is working at Punjab Agricultural University, Ludhiana. The total rodent fauna of the state comprises of species namely *Bandicota bengalensis*, *Tateta indica*, *Millardia meltada, Mus musculus*, *M. booduga*, *M. platythrix*, *Golunda ellioti*, *Nesokia indica, R. rattus, Funambulus pennanti* and *Hystrix indica.*

Damage to agricultural and horticultural crops is caused mainly by *B. bengalensis, T. indica, M. meltada, Mus* spp. and *F. pennanti.* Among these, *B. bengalensis* is the most predominant rodent pest species in all the agro-climatic zones of Punjab and has also turned out to be commensal in recent years. Survey of urban locales in Ludhiana revealed cohabitation of *B. bengalensis, R. rattus* and *M musculus.* On the other hand *T. indica* is widespread in dry farming conditions, whereas, other species are found in both irrigated and dry farming

situations. The species with restricted distribution is Indian bush rat, *G. ellioti* which has been reported from sugarcane, fodder and grass fields.

Earlier, *N. indica* used to be trapped sporadically from cereal and vegetable crops, however in recent years, its presence has been reported from crop fields and orchards in kandi area of Punjab. Other species in Kandi area of district Hoshiarpur include *T. indica* and *M. booduga*. Large burrow complexes of *N. indica* with heaps of loose soil near the burrow openings were found in wheat crop field also.

Rice, wheat, sugarcane and ground nut crops are the most vulnerable from rodent damage point of view. Earlier reports of 1980-90s, rodent damage to rice and wheat was 4.9 and 4.5% at pre harvest, which has came down to 1.2 and 1.5% respectively during the last 7-8 years. However wheat crop suffers higher damage under zero tillage (3.7%) and under happy seeder sown situations (4.2%). On the other hand rodent damage has increased in sugarcane from 6.4 to 13.8 and in ground nut from 3.9- 9.2% during this period. Other crops like maize, summer mung, muskmelon, summer squash, squash melon, brinjal, cauliflower, carrot and pea, the rodent damage varried from 0.83-23.63% during last 7-8 years. Rodent damage patterns reveal that damage to summer squash and tomato crops was maximum in the month of May and to muskmelon in July which may be due to increase in sweetness in fruits during this period. *B. bengalensis* was the predominant species in all the crops.

Regular monitoring of rodent damage at different crop stages of rice and wheat crops have revealed that ear head stage is the most vulnerable stage for rodent activity in terms of damage. Records of rodent damage in sugarcane fields at monthly intervals have revealed that rodents start damaging the crop in the month of September (when the sugar content starts increasing) and continues till harvest. Higher damage reported in sugarcane crop not harvested till January-February may be due to migration of rodents from surrounding fields. Survey of cotton fields in district Bathinda (cotton belt area) revealed rodent damage in the crop during and after germination and at fruit picking stage.

A survey of rodent damage to wheat, rice, basmati and cotton crops in villages of 16 districts namely Mansa, Jalandhar, Sangrur, Faridkot, Muktsar, Hoshiarpur, Ferozepur, Roop Nagar, Amritsar, Gurdaspur, Bathinda, Shahid Bhagat Singh (SBS) Nagar, Tarn Taran, Sahibjada Ajit Singh (SAS) Nagar, Barnala, Moga and Kapurthala during the years 2008-09 to

2016-17 revealed rodent damage up to 1.7% in rice, 1.1% in basmati crop and up to 3.9% in wheat. Yield loss (kg/ha) was up to 186.3 in rice, 15.5-76.3 in basmati crop and 1.9-241.9 in wheat (Table 20).

A survey of rodent damage to sugarcane crop in 22 villages of four major sugarcane growing districts namely, Ludhiana, Jalandhar, SBS Nagar and Kapurthala revealed rodent damage to the tune of 1.5-50.7% with yield loss ranging from 1.2-40.5 q/0.4ha (Table 21).

Table 20. Rodent damage to different crop in Punjab

Crop	Period	District	Cut tillers (%)	Yield loss (Kg/ha)
Rice	Oct. 2008	Mansa	0.7±0.3	109.0±34.7
	Oct. 2009	Jalandhar	0.5±0.04	86.7±9.0
		Sangrur	0.1±0.02	18.0± 4.2
	Oct. 2010	Faridkot	0.0±0.0	6.7±6.4
		Muktsar	0.0±0.0	0.0±0.0
	Oct. 2012	Hoshiarpur	0.3±0.04	20.1±2.1
		Ferozepur	0.8±0.1	83.7±3.6
	Oct. 2013	Roop Nagar	1.7±0.1	186.3±24.9
		Amritsar	0.9±0.3	84.3±22.1
		Gurdaspur	1.0±0.1	104.6±16.0
		Bathinda	1.0±0.1	85.3±0.7
	Oct. 2014	SBS Nagar	0.5±0.2	41.9±13.2
		Tarn Taran	0.9±0.6	79.8±9.5
	Oct. 2015	Mansa	0.5±0.2	56.3±24.0
		Sangrur	1.3±0.3	57.5±5.0
		Barnala	0.3±0.03	21.6±3.3
	Oct. 2016	Muktsar	0.2±0.0	15.1±1.0
		Bathinda	1.1±0.2	47.1±9.4
		Moga	0.6±0.2	38.5±11.5
Basmati rice	Nov. 2011	Faridkot	1.1±0.1	65.5± 1.9
		Moga	1.1±0.5	76.3± 38.7
	Nov. 2012	Hoshiarpur	0.2±0.1	20.0±8.2

Crop	Period	District	Cut tillers (%)	Yield loss (Kg/ha)
		Ferozepur	0.1±0.1	15.5±0.6
Wheat	Apr. 2008	Mansa	0.2±0.5	8.0±1.0
	Apr. 2009	Jalandhar	1.1±0.2	47.2±13.7
		Sangrur	0.1±0.03	3.7±2.0
	Apr. 2010	Faridkot	0.6±0.3	21.2±9.2
		Muktsar	1.0±0.3	47.3±12.6
	Apr. 2012	Hoshiarpur	1.0±0.2	41.4±6.3
		Ferozepur	0.1±0.0	1.9±1.6
	Apr. 2013	Roop Nagar	0.7±0.4	79.7±35.7
		Amritsar	1.5±0.6	82.8±31.3
		Gurdaspur	3.9±2.0	241.9±117.2
	Apr. 2014	SAS Nagar	1.8±0.4	179.6±46.1
		Tarn Taran	1.8±0.2	136.6±14.1
	Apr. 2015	Kapurthala	3.3±0.7	199.5±41.2
		Tarn Taran	3.4±0.9	79.3±22.3
	Apr. 2016	Mansa	0.9±0.6	40.9±26.4
		Sangrur	1.2±0.1	61.9±6.4
		Barnala	1.7±0.0	86.4±6.8

In grain stores, residential areas, poultry farms and cold stores, there is predominance of *R. rattus* followed by *M. musculus.* Survey of rural and commercial storage conditions in different villages of districts Ludhiana and Jalandhar revealed considerably less rodent damage under rural storage conditions because of indigenous storage practices being followed by the farmers.

Live Burrow count (LBC) of different rodent species on the basis of characteristic burrow entrances after harvest was recorded in wheat, rice, basmati rice and cotton crops in villages of sixteen districts namely Mansa, Jalandhar, Sangrur, Faridkot, Muktsar, Hoshiarpur, Ferozepur, Roop Nagar, Amritsar, Gurdaspur, Bathinda, Shahid Bhagat Singh Nagar, Tarn Taran, Barnala, Moga and Kapurthala representing all the five agro climatic zones in the years

Table 21. Rodent damage to sugarcane in major sugarcane growing districts of Punjab

District	Village	Canes damaged (%)	Yield loss Q/0.4ha
Ludhiana	Jaspal Bangre	22.4 ± 6.1	17.9 ± 4.8
	Lakhowal	9.3 ± 3.7	7.5 ± 2.9
	Mehlon	32.8 ± 8.7	26.2 ± 6.9
	Ladhowal	6.2 ± 4.0	5.0 ± 3.2
	Chack Kalan	1.7 ± 1.7	1.4 ± 1.4
Jalandhar	Apra	15.0 ± 10.7	12.0 ± 8.5
	Bachhowal	50.7 ± 9.2	40.5 ± 7.4
Shahid Bhagat Singh Nagar	Bahara	16.2 ± 6.2	12.9 ± 5.0
	Mirpurlakha	33.0 ± 13.0	26.4 ± 10.4
Kapurthala	Aujala	34.8 ± 11.1	27.8 ± 8.9
	Dhaliwal Dona	7.5 ± 2.9	6.0 ± 2.3
	Dhuanke Nisan	7.3 ± 2.6	5.8 ± 2.1
	Wadala Khurd	4.4 ± 2.1	3.5 ± 1.7
	Wadala Kalan	8.7 ± 3.4	7.0 ± 2.7
Ludhiana	Rayian	29.1 ± 3.7	23.2 ± 3.0
	Bhagpur	16.6± 0.8	13.3 ± 0.6
	Lakhowal	14.6± 1.7	11.6 ± 1.3
Jalandhar	Surgundh	1.9 ± 0.8	1.5 ± 0.6
	Muthada Kalan	2.0 ± 1.0	1.6 ± 0.8
	Thalla	11.5 ± 4.1	9.2 ±3.3
	Bhar Singhpura	1.5 ± 1.2	1.2 ± 1.0
	Raipur araian	18.4 ± 5.2	14.7 ± 4.2

2009-10 to 2016-17. Data revealed the predominance of *B. bengalensis* followed by *M. booduga, T. indica* and *M. meltada* with total burrows per hectare ranging from 11.1 to 83.0 in rice crop, 4.9 to 59.9 in basmati rice crop, 5.2 to 105.2 in wheat crop and 11.2 to 55.6 in cotton crop (Table 22).

Table 22. Post-harvest burrow count in crop fields

Crop	Period	District	No. of rodent burrows /ha (Mean ± SE)				
			Bb	*Mb*	*Ti*	*Mm*	Total
Rice	Oct. 2009	Jalandhar	17.5±1.2	15.8±2.4	3.2±0.7	0.0±0.0	36.5±0.7
		Sangrur	4.7±1.2	7.0±0.5	1.2±0.7	1.0±0.2	14.2±1.7
	Oct. 2010	Faridkot	0.0±0.0	0.0±0.0	2.5±2.0	13.3±3.0	15.8±2.01
	Oct. 2012	Hoshiarpur	12.5±1.0	18.5±8.7	2.5±2.0	9.7±3.0	43.2±14.7
		Ferozepur	9.2±0.5	5.7±0.5	0.0±0.0	0.0±0.0	14.9±0.0
	Oct. 2013	Roop Nagar	-	-	-	-	83.0±7.7
		Amritsar	-	-	-	-	53.2±7.7
		Gurdaspur	-	-	-	-	57.7±6.0
		Bathinda	22.5±1.0	0.7±0.7	31.2±0.7	0.0±0.0	54.4±2.2
	Oct. 2014	SBS Nagar	35.0±12.5	7.2±3.7	0.0±0.0	1.4±1.1	43.6±11.0
		Tarn Taran	17.2±1.0	9.5±1.2	0.0±0.0	0.0±0.0	26.7±4.2
	Oct. 2015	Mansa	8.4±1.6	8.1±0.6	2.0±1.0	4.7±1.2	23.2±3.5
		Sangrur	5.6±1.2	4.1±0.7	10.6±0.8	1.0±0.4	21.2±2.6
		Barnala	10.6±1.9	6.7±0.6	-	1.2±0.1	18.4±5.6
	Oct. 2016	Muktsar	9.4±1.6	4.1±1.1	-	-	13.6±2.7
		Bathinda	5.7±0.7	2.9±0.5	2.6±0.5	-	11.1±1.4
		Moga	8.8±1.2	5.9±1.1	-	-	14.8±2.1
Basmati	Nov. 2011	Faridkot	10.7 ±4.0	0.0±0.0	0.0±0.0	19.2± 8.2	29.9 ±12.2
		Moga	32.5±4.2	4.5±0.7	0.0±0.0	2.0±0.1	39.0±4.2
	Nov. 2012	Ferozepur	1.7±0.7	3.2±1.7	0.0±0.0	0.0±0.0	4.9±1.2
		Hoshiarpur	19.2±4.0	29.5±8.4	1.2±0.7	10.0±4.7	59.9±7.7

Crop	Period	District	No. of rodent burrows /ha (Mean ± SE)				
			Bb	*Mb*	*Ti*	*Mm*	Total
Wheat	Apr. 2008	Mansa	2.7± 0.5	2.7± 0.5	6.0±2.0	0.7±0.5	12.1±0.7
	Apr. 2009	Jalandhar	16.2±2.7	8.0±2.0	0.4±0.2	0.0±0.0	22.5±4.5
		Sangrur	3.5±0.2	2.2±1.0	1.0±0.5	0.5±0.2	8.2±1.0
	Apr. 2011	Faridkot	0.0±0.0	0.0±0.0	5.0±1.2	0.2±0.2	5.2±1.0
	Apr. 2012	Hoshiarpur	10.5±1.7	13.7±13.7	14.0±1.0	0.0±0.0	38.2 ±13.5
	Apr. 2013	Roop Nagar	6.0±2.2	3.5±1.2	0.0±0.0	0.0±0.0	9.5±2.7
		Amritsar	62.7±8.7	39.5±1.7	3.0±1.2	-	105.2±11.0
		Gurdaspur	41.5±9.5	13.5±1.5	1.2±0.5	-	55.9±10.0
	Apr. 2014	SAS Nagar	15.5±3.2	-	-	-	15.5±3.2
		Tarn Taran	46.0±3.7	15.2±1.0	-	-	61.2±3.2
	Apr. 2015	Kapurthala	10.2±0.7	-	-	-	10.2±0.7
		Tarn Taran	7.6±1.4	2.7±0.7	-	-	10.2±2.1
Cotton	Oct. 2010	Faridkot	0.5±0.2	0.0±0.0	2.7±1.7	8.0±1.0	11.2±3.5
	Nov. 2011	Muktsar	30.7±13.0	-	0.2±0.2	-	30.9±12.7
	Oct. 2013	Bathinda	23.0±1.2	1.2±1.0	30.0±3.2	1.4±1.0	55.6±1.2

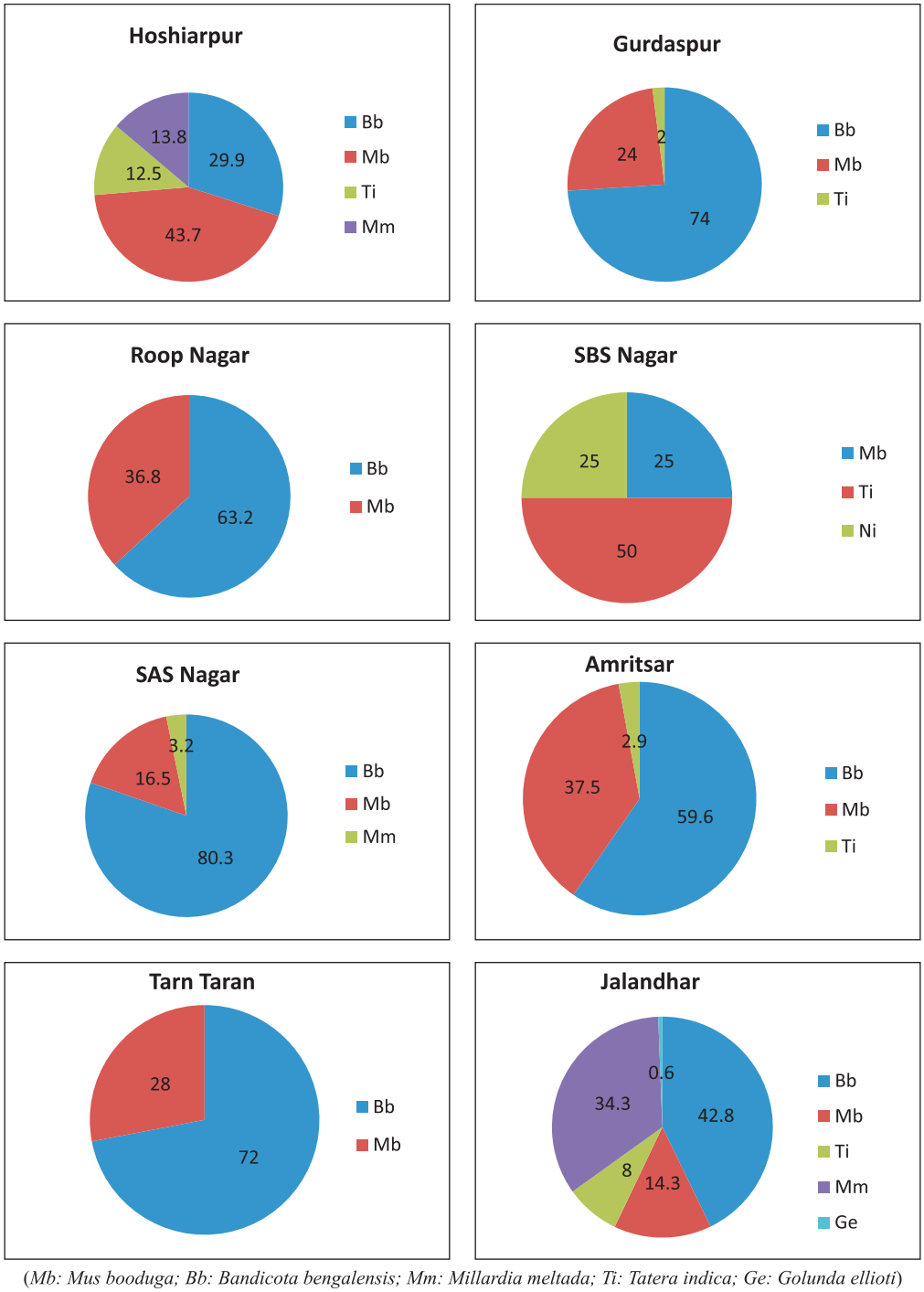
Bb: *Bandicota bengalensis; Mb: Mus booduga; Ti: Tatera indica; Mm*: *Millardia meltada*

Survey of 17 districts under five agro-climatic zones have revealed slight variation in rodent species composition in Punjab. *B. bengalensis* is the predominant species in districts Gurdaspur, Roop Nagar, SAS Nagar, Amritsar, Taran Taran, Jalandhar, Kapurthala, Ludhiana, Ferozepur, Moga and Muktsar; *M. booduga* is predominant in districts Hoshiarpur and Sangrur; *T. indica* is the predominant species in SBS Nagar, Bathinda and Mansa and *M. meltada* is the predominant species in Faridkot district (Table 23, Fig. 13).

Table 23. Rodent species composition in different agro-climatic zones of Punjab

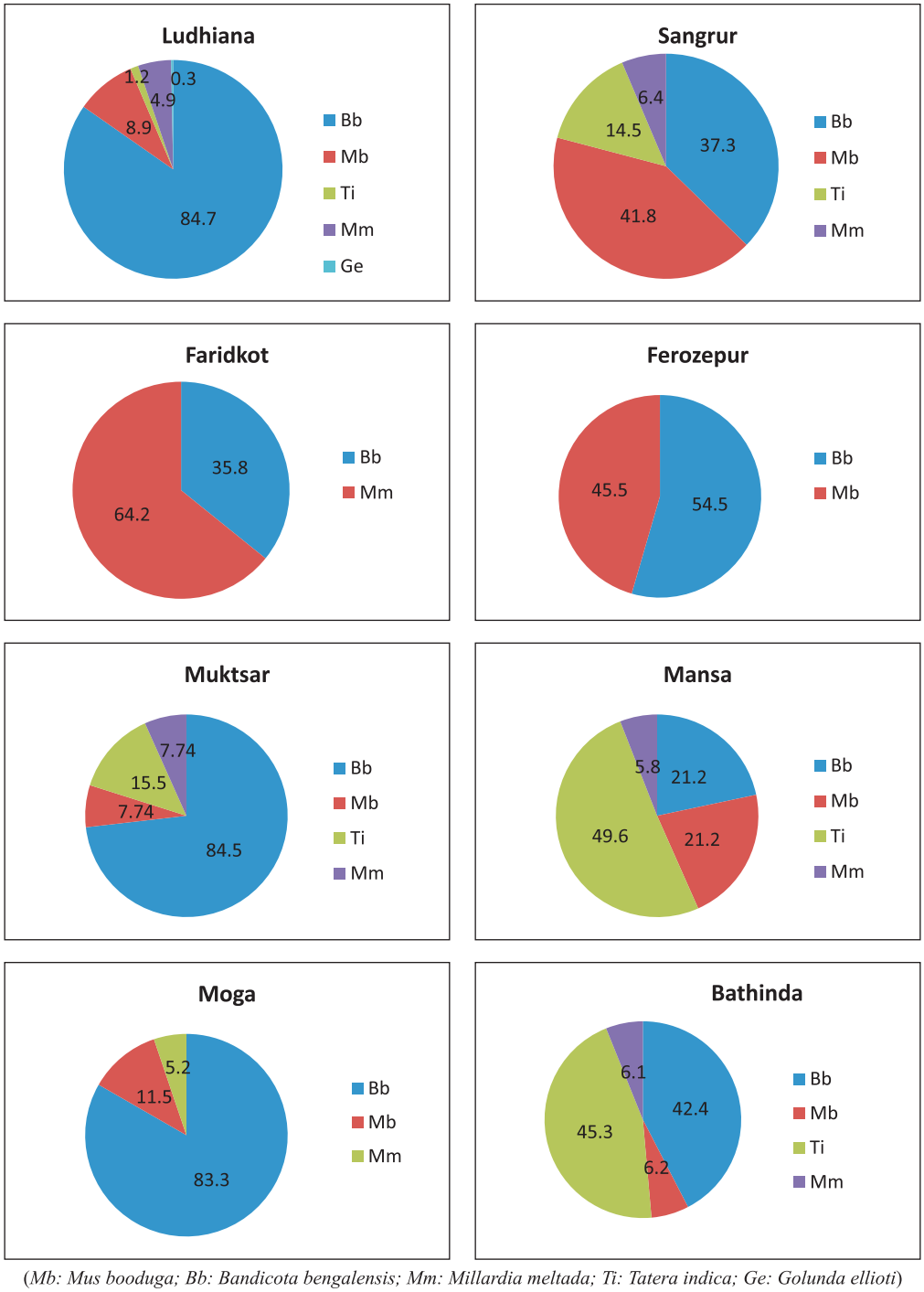
Agro-climatic zone	District	Rodent species
Sub mountain undulating zone	Hoshiarpur	*Mb>Bb>Mm>Ti*
	Gurdaspur	*Bb>Mb>Ti*
Undulating plain zone	Roop Nagar	*Bb>Mb*
	Shahid Bhagat Singh Nagar	*Ti>Mb>Ni*
	Sahibjada Ajit Singh Nagar	*Bb>Mb>Mm*
Central plain zone	Amritsar	*Bb>Mb>Ti*
	Tarn Taran	*Bb>Mb*
	Jalandhar	*Bb>Mm>Mb>Ti>Ge*
	Kapurthala	*Bb*
	Ludhiana	*Bb>Mb>Mm>Ti>Ge*
	Sangrur	*Mb>Bb>Ti>Mm*
Western plain zone	Faridkot	*Mm>Bb*
	Ferozepur	*Bb>Mb*
Western zone	Bathinda	*Ti>Bb>Mb>Mm*
	Moga	*Bb>Mb>Mm*
	Muktsar	*Bb>Ti>Mm=Mb*
	Mansa	*Ti>Bb=Mb>Mm*

(*Mb: Mus booduga; Bb: Bandicota bengalensis; Mm: Millardia meltada; Ti: Tatera indica; Ge: Golunda ellioti*)



(*Mb: Mus booduga; Bb: Bandicota bengalensis; Mm: Millardia meltada; Ti: Tatera indica; Ge: Golunda ellioti*)

Figs. 13. Rodent species composition in different districts of Punjab



(*Mb: Mus booduga; Bb: Bandicota bengalensis; Mm: Millardia meltada; Ti: Tatera indica; Ge: Golunda ellioti*)

Figs. 13. Rodent species composition in different districts of Punjab

9. RAJASTHAN

Rajasthan lies in the North West of India. The climate is generally hot and dry with temperature ranging from 32°C to 45°C. On the basis of climatic conditions and agricultural produce, it is divided into nine agro-climatic zones viz., 1. Arid Western Plain, 2. Irrigated North-Western Plains, 3. Transitional Plain of Inland Drainage, 4. Transitional Plain of Luni Basin, 5. Semi-arid Eastern Plain, 6. Flood Prone Eastern Plains, 7. Sub-humid Southern Plains & the Aravalli Hills, 8. Humid Southern Plains, 9. Humid South-Eastern Plains.

The center of AINP on VPM (Rodent Control) for Rajasthan state is working at ICAR-Central Arid Zone Research Institute, Jodhpur. Survey during the last 7-8 years revealed that rodent fauna of Rajasthan consists of species like Indian gerbil, *Tatera indica;* Indian desert gerbil, *Meriones hurrianae;* Indian hairy footed gerbil, *Gerbillus gleadowi;* Balochistan gerbil, *Gerbillus nanus indus; Cutch rock rat, Cremnomys cutchicus;* Sand coloured rat, *Rattus gleadowi;* house rate, *Rattus rattus;* soft furred field rat, *Millardia meltada;* mole rat, *Bandicota bengalensis;* short tailed mole rat, *Nesokia indica;* Asiatic long tailed climbing mouse, *Vandeleuria oleracia;* Fawn coloured mouse, *Mus cervicolor; M. platythrix; M. booduga*; bush rat, *Golunda ellioti* northern palm squirrel, *Funambulus pennanti* and *Hystrix indica.* Amongst these, *T. indica* and *M. hurrianae* are most predominant species in arid regions.

Survey conducted during kharif and rabi season (2013-2016) in Narmada Canal Command area revealed presence of *M. hurrianae* (22.54%), *T indicia* (32.97%), *M. meltada,* (13.37%), *G. ellioti (*15.87%) and *F. pennanti* (21.74%) in the fields and *R. rattus* (20.65%) and *M. musculus* (12.15%) in dhanis and field stores. Fields where cultivation of irrigated crops was in vogue for more than 30 years, *M. hurrianae* was not observed, however in the fields where cultivation of irrigated crops started after advent of canal (2008), *T. indica* was predominant (21-44%) followed by *M. hurrianae* (14.29-33.33%) in the crop fields.

Rodent damage to various crops in the last 7-8 years (Table 24) revealed that isabgol and cumin the two most important cash crops of the region suffers heavily (up to 50% plant damage) in peripheral regions of crop fields. Other crops viz, wheat, mustard and pulses experience rodent damage to the tune of 3-20%, 10-12% and 2.0-8.5%, respectively in arid Rajasthan. In Kachch region of Gujarat, sugarcane and cotton crops suffer 13.1 and 3,4% damage to canes and bolls, respectively. Young saplings of date palm were damaged to the tune of 2.0-10.4% by *M. hurrianae*.

Table 24. Rodent damage to different crops in Rajasthan

Year	Location	Month	Crop	Percent damage
2009	Setrava	Jan	Isabgol	15.0
	Kalu		Cumin	10.0
	Khiasar		Castor	2.0
	Chirdia	Feb	Isabgol	40.0-50.0
			Wheat	15.0-20.0
			Mustard	10.0-12.0
			Onion	5.0
			Castor	2.0-3.0
	Berai	Feb	Isabgol	50.0
	Haran, Gova Kala & Inania	Jul	Moong	2.0-3.0
2010	Jhunjhunu	Aug	Bajra, Moong & Sorghum	2.0-4.0
2011	Bijwadia & Pipasani	Jan, Mar	Isabgol	1.2-11.8
			Wheat	3.0-7.2
			Cumin	1.2-12.4
			Mustard	10.0
	IGNP area (Bikaner & Lunkaransar)	Mar	Pea, Gram Cucumber	6.0-8.5
	Kachh (Gujarat)	Nov	Sugarcane	13.1
			Cotton	3.4
	Khichan (Phalodi)	Nov	Date palm	2.0-10.4
2012	IGNP area (Sri Ganganagar)	Mar	Wheat	8.53
2014	Sanchore	Feb	Cumin	7.6-50.8
			Wheat	16.2
2016	Sanchore		Cumin	7.6

In Indira Gandhi canal command areas, groundnut crop experienced an average damage of 12- 17.5%. The crop recorded maximum damage in peripheral areas (34.7%) in Lunkaransar (Bikaner). Cotton crop suffered up to 6.7% plant damage in Sri Ganganagar District. Mung registered 4.2 % (Lunkaransar) and 9.3% (Sri ganganagar) rodent damage. Similarly, guar, an important cash crop of the region experienced lower damage in Sri Ganganagar (1.9%) than that in Lunkaransar (6.6%). Rice infested with 1-6 burrows/m^2 in Suratgarh area experienced up to 14.3% damage to tillers.

Impact of changes in land use pattern on rodent fauna in arid zone: Changes in land use patterns in arid regions have greatly influenced rodent species composition. To monitor such

changes studies were undertaken in CR farm of the institute (CAZRI), which has witnessed transformation from a typical sandy plains/hummocks into well established farming systems like Horticulture, slvi-pasture and agri-pasture, crop fields etc and residential areas during last 4-5 decades. To monitor the impact of these changes on rodent diversity, long term surveys were carried out in three major systems viz, Horticulture, slvi-pasture and agri-pasture. Earliest available reports (1970) of rodent species of the area indicated presence of three truly desertic rodent fauna viz., *Meriones hurrianae, Gerbillus gleadowi, G. nanus* and *Mus cervicolor.* Other rodent inhabitants in the area were *T. indica, M. meltada* and *F. pennanti.* Recent reports indicated major shift in species composition. Although *T. indica* maintained its predominance with 60-80% share, the truly desertic fauna viz., *M. hurrianae, G. gleadowi, G. nanus* and *M. cervicolor* have been completely replaced. Instead *M. millardia, G. ellioti, M. booduga* have entered the area. Two commensal rodents *R. rattus* and *M. musculus* too have shown their presence in varying proportions. The population of *F. pennanti* has increased manifold ranking second in species composition mainly in horticultural fields (Table 25).

Habitat wise distribution of rodents indicated that the horticulture fields were preferred the most (mean of last five years: 44.49%) followed by Silva-pasture (mean 28.95%) and Agri-pasture (mean 26.58%).

Incidence of *B. bengalensis* in arid regions: *B. bengalensis,* primarily a wild mesic species, due to its remarkable adaptability to diverse ecological condition and human intervention has established itself as an important rodent pest by replacing native rodents in various habitats, viz., cultivated fields, pasture lands, and semiarid regions, rural and urban areas across the country. However, it was not reported from extreme western desert regions except in urban locales of Bikaner city. In Jodhpur, it was first reported in 2001, since then regular surveys are continued to record incidence/spread of this unwanted colonizing rodent in Jodhpur town, the gateway of Indian desert. Bi-monthly collection of *B. bengalensis* from urban locales of Jodhpur revealed spread of the species in outskirts of the city area along the channel carrying city waste. The mean trap index ranged between 0.048-0.068 rodents/trap/day during the last 5-6 years with a maximum population in winter months. The body weight in the collection irrespective of year ranged between 58-389 g with lightest and heaviest female of 68 & 350 g and male of 58 & 389 g, respectively. Lower body weight was recorded in summer compared to that during monsoon

Table 25. Changes in rodent species composition in CR Farm of CAZRI, Jodhpur during last five years

Rodent species	1970	2011	2012	2013	2014	2015
Tatera indica	43.8	84.2	79.79	63.29	83.90	75.27
Funambulus pennanti	0.82	11.89	14.26	31.65	13.56	12.90
Mus musculus	0	1.62	1.60	1.27	0.85	0
Rattus rattus	0	2.16	4.26	3.16	1.65	11.83
Millardia meltada	0.82	pr	0	0.63	0	0
Merionaes hurrianae	28.9	0	0	0	0	0
Gerbillus gleadowi	0.82	0	0	0	0	0
G. nanus	24	0	0	0	0	0
Mus booduga	0	Pr	Pr	Pr	Pr	0
Gollunda ellioti	0	Pr	Pr	Pr	Pr	Pr
Mus cervicolor	0.82	0	0	0	0	0
Histryx indica	0	0	0	0	Pr	Pr
Total number of species	**07**	**07**	**06**	**07**	**07**	**05**

and winter collections. The sexually mature male and females were available through the year, as in every catch more than 50% collection constituted sexually mature individuals. Similarly, pregnant females were trapped round the year with a slight peak during monsoon and winter months.

NATIONAL SCENARIO OF RODENT PESTS AND CROP DAMAGE

Data generated on rodent pest species and crop damage in different states of India is summarized in Tables 26 and 27. Andaman and Nicobar Islands are infested by three species of rats and one species each of mouse and squirrel. Andhra Pradesh suffers crop damage mainly by two rat species and one mouse species. Likewise in Arunachal Pradesh three rat species and two species of mouse and one species of squirrel are the major problem species in crops and horticulture. In Assam, seven rat species, two mice and one squirrel species are regarded as problem species in fields and storage. In Karnataka, three rat species, one gerbil, three species of mouse and one squirrel are major problem in agriculture, horticulture including plantation crops. Field crops in Odisha experience infestation of three rat and one mouse species. Punjab is infested by five rat species, one gerbil, three mice species, one squirrel and one porcupine. Rajasthan is inhabited by large number of species, but problem species in agriculture, horticulture, forestry and grasses in arid Rajasthan include four rats, three gerbils, three mouse one squirrels and a porcupine. In Leh-Ladakh region of Jammu and Kashmir, one mouse, one rat and one vole species have been reported to be problem species in field and storage.

The information compiled shows rich rodent pest fauna in India leading to heavy damage to various crops at different stages. There is sufficient information on relative abundance of rodent species/species complexes in different agroclimatic zones of the country, extent of damage and the vulnerable crop stages across the country. This information will certainly help in improving and developing rodent pest management strategies for different crops of the country.

In overall, damage due to rodents has been reported to be upto 24.5% in rice, 20% in wheat, 7.2% in other cereals, 50.7% in sugarcane, 12.4% in maize, 13.1% in groundnut, 4.2% in cotton, 46.6% in vegetables, 42.1% in plantation crops, 8.5% in pulses, 12.4% in spices, 12% in mustard and toria and 12.8% in niger crops in India.

Table 26. Distribution of Rodent pest species in India

State/Union Territory	Type of rodent	Number of species	Rodent species
Andaman and Nicobar Islands	Rats	3	*Rattus rattus, Rattus burrescens, Bandicota. bengalensis*
	Mouse	2	*Mus musculus, Mus booduga*
	Squirrel	1	*Funambulus pennanti*
Andhra Pradesh	Rats	2	*Bandicota bengalensis, Rattus rattus*
	Mouse	1	*Mus booduga*
Arunachal Pradesh	Rats	3	*Rattus rattus, Bandicota bengalensis, Rattus sikkimensis*
	Mouse	1	*Mus cookie nagarum*
	Squirrel	1	*Hylopetes alboniger*
Assam	Rats	7	*Bandicota bengalensis, Bandicota indica, Rattus sikkimensis, Rattus nitidus, Rattus rattus, Niviventer niviventer, Niviventer fulvescens*
	Mice	2	*Mus booduga, Mus musculus*
	Squirrel	1	*Dremomys lokriah macmillani*
Jammu & Kashmir	Mice	1	*Mus booduga*
	Rat	1	*Rattus turkestanicus*
	Vole	1	*Pitymys leucurus*
Karnataka	Rats	3	*Bandicota bengalensis, Millardia meltada, Rattus rattus*
	Gerbil	1	*Tatera indica,*
	Mice	3	*Mus booduga, Mus musculus, Mus platythrix*
	Squirrel	1	*Funnambulus palmarum*
Punjab	Rats	4	*Bandicota bengalensis, Nesokia indica, Millardia meltada, Rattus rattus*
	Gerbils	1	*Tatera indica,*
	Mice	3	*Mus booduga, Mus musculus, Mus platythrix*
	Squirrel	1	*Funambulus pennanti*
	Porcupine	1	*Hystrix Indica*
Rajasthan	Rats	4	*Bandicota bengalensis, Nesokia indica, Millardia meltada, Rattus rattus*
	Gerbils	3	*Tatera indica, Meriones hurrianae, Gerbillus gleadowi,*
	Mice	3	*Mus platythrix, Mus booduga, Mus musculus*
	Squirrel	1	*Funambulus pennanti*
	Porcupine	1	*Hystrix Indica*

Table 27. Rodent damage to different crops in India

State/Union Territory	Crop	Rodent damage (%)
Andaman & Nicobar Islands	Coconut	4.2-6.2
	Brinjal	5.7-46.6
	Tomato	8.3-33.9
	Rice	3.7-18.2
Andhra Pradesh	Rice	4.1-16.6
	Sugarcane	1.8-13.5
	Maize	1.0-5.0
	Coconut	2.1-11.9
	Cocoa	1.7-7.3
	Groundnut	13.1
	Cotton	4.2
Arunachal Pradesh	Rice	0-24.5
	Sugarcane	2.8-3.1
	Maize	0-12.4
	Cassava	0.7-18.4
	Vegetables	2.3-15.5
Assam	Rice	2.0-17.6
	Wheat	9.0-12.6
	Toria	10.2
	Sugarcane	14.0-14.2
	Vegetables	10.1-16.4
	Niger	12.8
	Pummelo	42.1
	Arecanut	40.8
Karnataka	Rice	2.2-7.5
	Wheat	3.6-5.6
	Maize	1.0-4.2
	Sorghum	1.5-5.8
	Ragi	1.6-7.2

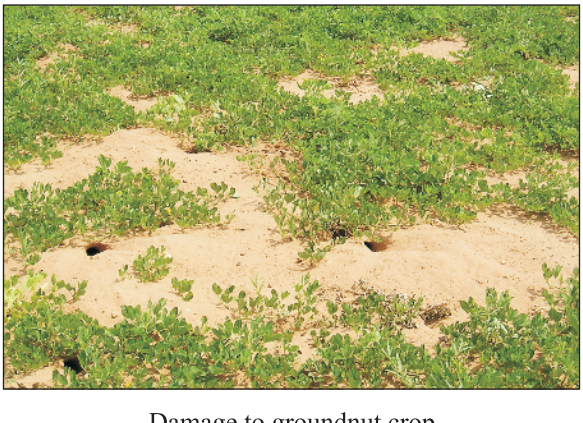
State/Union Territory	Crop	Rodent damage (%)
	Groundnut	0.9-8.6
	Vegetables	2.5-7.3
	Pulses	1.6-7.3
	Cardamom	1.5-12.4
	Sesame	1.2-9.6
	Cashew nut	1.1-6.3
	Coffee	6.0-7.0
	Coconut	1.6-14.8
	Grapes	6.1-6.4
	Pine apple	2.3-5.8
Punjab	Rice	0-1.7
	Basmati	0.1-1.1
	Wheat	0.1-3.9
	Sugarcane	1.5 to 50.7
Rajasthan	Wheat	3.0-20.0
	Sugarcane	13.1
	Mustard	10.0-12.0
	Cotton	3.4
	Isabgol	1.2-50.0
	Cumin	1.2-12.4
	Pulses	2.0-8.5
	Date palm	2.0-10.4
	Moong	2.0-3.0
	Bajra & Sorghum	2.0-4.0
	Pea, Gram & Cucumber	6.0-8.5

Damage to rice crop

Damage to wheat crop

Damage to wheat crop sown with Happy Seeder

Damage to sugarcane crop



Damage to groundnut crop

Damage to cotton crop

Plate 3: Rodent damage in crops

Damage to bottle gourd

Damage to ash gourd

Damage to kakri

Damage to water melon

Damage coaco

Damage to pomegranate

Plate 4: Rodent damage in vegetables and fruits

SUMMARY

The reports of AINP on Vertebrate Pest Management centers spread in various agro-ecologies of the country, as discussed above reveal that rodent pests inflict on an average 5-25% damage to arable and perennial crops across the country. In fact pest status of rodent species is a combination of cropping pattern of the region *vis-à-vis* eco-biology of rodent species. Generally crop fields are homogeneous and man made ecosystem with a plant community dominated by one or two crop species. Depending upon the availability of water, climate suitability and the soil fertility, different crops are grown in an area, which regularly supply energy rich food to rodents in a limited area. Therefore the availability of food and cover to native rodents are continuous with different crops grown in different seasons in fields. The rodent species that can take advantage of the temporarily abundant food and at the same time somehow overcome the periods when the conditions are poor, make rodents' a good candidate as agricultural pests. Thus agricultural fields serve as a highly productive rodent habitat.

India, being a highly diverse country, more than a dozen species are regarded as pests in agriculture and storage. Most of the pest species belong to family muridae, followed by three species of sciuridae and one species in Hystricidae. However, a pest complex of 2-4 rodent species occurs in any particular agro-climatic region/ cropping system. The lesser bandicoot rat, *Bandicota bengalensis* is the most predominant rodent pest species in India and is well distributed in crop fields and residential areas all over the country, except the extreme hot arid regions and Islands). However in recent years the lesser bandicoots have knocked the doors of not only the Indian desert but also in Andaman and Nicobar Islands and NEH regions. Other species of national importance in the fields are *Millardia meltada*, *Tatera indica* and *Mus booduga.* Two species, viz., *Meriones hurrianae* and *Gerbillus gleadowi* have limited distribution in arid areas of western Rajasthan. Similarly the Himalayan rat, *Rattus nitidus*, Bowers rat, *Rattus bowersi*, white bellied rat, *Rattus (Niviventer) niviventer* are restricted to north-eastern hill region only. In plantation crops viz., coconut, *Rattus rattus wroughtoni* is a major probleatic species. Among squirrels, *Funambulus pennanti* inhabits fruit orchard in North India and *F. tristriatus* in plantation crops in South India. Among various crops, sugarcane, rice, wheat, groundnut, fodder crop fields and coconut orchards serve as an ideal habitat for rodent pests and therefore suffer heavy damage. Similarly threshing yards located near crop fields too act as an excellent abode for food and shelter of rodents. NEH region with vast areas under bamboo forests suffer extensive damage to native crops during gregarious flowering of certain bamboo species due to rodent outbreak in certain years.

CAZRI™

Enhancing resilience of arid lands