"Studies on habitat ecology of field rodents and their management in groundnut, *Arachis hypogaea* L."

ADARSH, K. K.

PALB 1285

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK, BENGALURU-560 065.

2013

“Studies on habitat ecology of field rodents and their management in groundnut, *Arachis hypogaea* L.”

ADARSH, K. K.

PALB 1285

Thesis submitted to the

UNIVERSITY OF AGRICULTURAL SCIENCES, BENGALURU

In partial fulfillment of the requirements

For the award of the Degree of

MASTER OF SCIENCE (Agriculture)

In

AGRICULTURAL ENTOMOLOGY

BENGALURU **August , 2013**

AFFECTIONATELY DEDICATED TO MY BELOVED PARENTS AND BROTHER

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES GKVK,
BENGALURU-560065

CERTIFICATE

This is to certify that the thesis entitled **"Studies on habitat ecology of field rodents and their management in groundnut,*Arachis hypogaea* L."** submitted by **Mr. ADARSH, K. K., PALB 1285** in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in **AGRICULTURAL ENTOMOLOGY**, to the University of Agricultural Sciences, Bengaluru is a *bonafide* record of research work done by her during the period of her study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associate-ship, fellowship or other similar titles.

BENGALURU

AUGUST, 2013

(DR. V. SHIVAYYA)
MAJOR ADVISOR

APPROVED BY:

Chairman: ________________________
(V. SHIVAYYA)

Members: **1.** ________________________
(A. K. CHAKRAVARTHY)

2. ________________________
(MOHAN I. NAIK)

3. ________________________
(G. GOVINDA RAJ)

4. ________________________
(R. MUNIRAJAPPA)

ACKNOWLEDGEMENT

"Real life is not always going to be perfect or go our way: But the recurring acknowledgement of what is working in our lives can help us not only survive but surmount our difficulties".

'Thank you', two words of sentiment expressed from depth of my heart for the sustained help and co-operation from those whom I received. It's my pride, pleasure respect and a depth of gratitude to acknowledge and remember.

I consider myself lucky to pursue Master of Science (Agriculture) in Department of Agricultural Entomology with the excellence and ever helpful personalities of our professors. I will forever be thankful to all of our ***course teachers, Dr. C. A. Viraktamath, Dr. B. Mallik, Dr. N. G. Kumar****, Professor,* ***Dr. V. V. Belavadi****, Professor,* ***Dr. N. Srinivasa,*** *Professor,* ***Dr. Govindaraj,*** *Professor,* ***Dr. A. R. V. Kumar,*** *Professor,* ***Dr. K. Chandrashekar,*** *Assoc. Professor,* ***Mr. A. H. Jayappa,*** *Assoc. Professor,* ***Mr. Shivamurthy Naik,*** *Assoc. Professor.* ***Dr. Chinnamade Gowda****, Assoc. Professor,* ***Dr. Thippaiah*** *Assoc. Professor,* ***Mr. K. V. Prakash****, Assistant Professor for their inspiring classes, guidance, critical comments, suggestions, continuous support, and encouragement through the post graduation programme.*

I would like to express my deep sense of gratitude and indebtedness to ***Dr. V. Shivayya,*** *Professor and* ***Dr. Mohan I. Naik,*** *Professor, AINP Rodent control, Department of Agricultural Entomology, UAS, GKVK, Bengaluru, for their guidance and valuable suggestions throughout my post graduation programme.*

I wish to express my heartfelt thanks to ***Dr. C. T. Ashok Kumar****, Professor and University Head, Department of Agricultural Entomology, UAS, GKVK, Bengaluru, for his encouragement and timely guidance during my course of study.*

I profusely thank ***Dr. A. K. Chakravarthy****, Professor and Head, Department of Agricultural Entomology, UAS, GKVK, Bengaluru, for his encouragement, support, concern, valuable suggestions and guidance during my course of study.*

It gives me an immense pleasure to thank, ***Dr. G. Govindaraj****, for his inspiring guidance, valuable suggestions, care and concern towards me.*

I thank to ***Dr. R. Munirajappa****, Associate Professor, Department of Agricultural Statistics for being supportive, helpful, and his assistance during all stages of study in the university.*

Man need an offbeat to relieve himself of tension, here it is my friends who come in so handy. I owe upstream thanks to ***Dhananjay, Raghavendra**, **Vishwa**, **Sameer, Suvana, Nithya, Arvind, Sandya, Anusha, Karthika, Aswathi, Parvathy, Arsha, Sameer Ali, Ashique, Marjana, Vyshak, Ajmal, Fredy and Amrutha*** *for their moral support and kind help rendered.*

I extend my sincere thanks to my seniors ***Veeresh, Murali, Basanagowda, Subash, Chandrashekaraiah, Prashanth, Arathi, Banu, Ziety, Muthu, Basavaraj, Sulthani*** *and juniors* ***Madu, Pathan, Sreenivas, Kumar*** *for their timely help and support.*

My most vocal and heartfelt thanks to ***Mr. Manjunath*** *and* ***other departmental staffs*** *for their at most care, continuous support, suggestions, encouragement throughout my post graduation.*

I wish to remember and never forget in my life the company of my classmates ***Swamy, Shambu, Prabu, Vasu, Santhosh, Pramod, Rani, Anuradha, Uma, Bhagya, Tharini, Abhilasha, Roopa, Geetha and Vidya*** *whose hands were evident at each and every moment of anxiety and achievements.*

I am unable to acknowledge adequately the selfless sacrifice and love of my father ***O. C. Vijayakumar*** *and my mother* ***Sivakumari**,. Yet I shell avail this opportunity to express my love to brother* ***Aravind*** *for his affection, and fun, which keep me out of worries and stress in responsible life.*

……. any omission in this brief acknowledgement doesn't mean lack of gratitude.

Bengaluru

August, 2013 **(ADARSH, K. K.)**

"Studies on habitat ecology of field rodents and their management in groundnut, *Arachis hypogaea* L."

ADARSH K. K.

THESIS ABSTRACT

The present investigation was conducted at Thagachuguppey village, Magadi Taluk of Ramanagara District of Karnataka state. Rodents were considered as a major vertebrate pest of groundnut. Rodent species observed in groundnut field during the study were *B. bengalensis, T. indica, M. booduga, M. platythrix* and *B. indica* in which the *B. bengalensis* (41.91%) and *T. indica* (32.8%) were dominant and the maximum population of rodents was recorded during harvesting season. The study indicated that burrow characteristics like length of the burrow, depth of the burrow, diameter of the openings and tunnels, number of burrow openings and number of side tunnels increases from germination to harvesting seasons irrespective of rodent species. Hoarding materials like groundnut pods, ragi grains and some weeds were quiet common in the burrows of *B.bengalensis* and *T. indica.* However, *Mus spp.* and *B. indica* as observed do not have hoarding habits. Litters were also observed in the burrows of all species except in *B. indica.* Among the treatments tested for management of rodents in groundnut found the best treatment was 2% Zn_3P_2 baiting at germination stage followed by Al2 $(PO_3)_2$ application in peg formation stage during *Kharif* season which give 82% reduction of rodents population and yield 1381kg/ha. Similarly in *summer* season best treatment was 2% Zn_3P_2 baiting at germination stage followed by Al2 $(PO_3)_2$ application in peg formation stage which give 76% of reduction in rodent population and highest yield of 1351.33 kg/ha. The C:B ratio was highest with Zn_3P_2 (2%) baiting at peg formation stage in both seasons, *Kharif* (1:38.12) and *summer* (1:36.56).

Department of Entomology — **V. Shivayya**

UAS, GKVK, Bengaluru-65 — (Major Advisor)

ಕಡಲೇಕಾಯಿಯಲ್ಲಿ ಕ್ಷೇತ್ರ ಇಲಿಗಳ ಆವಾಸಸ್ಥಾನದ ಪರಿಸರ ಅಧ್ಯಯನ ಮತ್ತು ಅವುಗಳ ನಿರ್ವಹಣೆ

ಆದರ್ಶ್ ಕೆ ಕೆ

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ತನಿಖೆತನ್ನು , ಕರ್ನಾಟಕ ರಾಜ್ಯದ ರಾಮನಗರ ಜಿಲ್ಲೆಯ ಮಾಗಡಿ ತಾಲ್ಲೂಕಿನ ತಗಚುಗುಪ್ಪೆಯಲ್ಲಿ ಗ್ರಾಮದಲ್ಲಿ ನಡೆಸಲಾಯಿತು. ಕ್ಷೇತ್ರ ಇಲಿಗಳು ಕಡಲೇಕಾಯಿಯ ಒಂದು ಪ್ರಮುಖ ಕಶೇರುಕ ಕೀಟ ಎಂದು ಪರಿಗಣಿಸಲಾಗಿದೆ. ಅಧ್ಯಯನದ ಸಮಯದಲ್ಲಿ ಕಡಲೇಕಾಯಿ ಕ್ಷೇತ್ರದಲ್ಲಿ ವೀಕ್ಷಿಸಲಾದಂತೆ ಜಾತಿಗಳು ಬಿ. ಬೆಂಗಾಲೆನ್ಸಿಸ್, ಟಿ ಇಂಡಿಕಾ, ಎಂ ಬೂದುಗ, ಎಂ ಪ್ಲಟಿಥ್ರಿಕ್ಸ್ ಮತ್ತು ಬಿ ಇಂಡಿಕಾ. ಇವುಗಳಲ್ಲಿ, ಕೊಯ್ಲು ಸಮಯದಲ್ಲಿ ಬಿ. ಬೆಂಗಾಲೆನ್ಸಿಸ್(41.91%) ಮತ್ತು ಟಿ ಇಂಡಿಕಾ (32.8%) ಪ್ರಬಲ ಮತ್ತು ಗರಿಷ್ಠ ಸಂಖ್ಯೆಯಲ್ಲಿ ಕಂಡುಬಂದಿವೆ. ಮೊಳಕೆಯ ಹಂತದಿಂದ ಕೊಯ್ಲು ಹಂತದವರೆಗೆ ಬಿಲ ಉದ್ದ, ಬಿಲ ಆಳದ, ತೆರೆಯುವಿಕೆಗೆ ಮತ್ತು ಸುರಂಗಗಳ ವ್ಯಾಸ, ಬಿಲ ರಂಧ್ರಗಳ ಸಂಖ್ಯೆ ಮತ್ತು ಅಡ್ಡ ಸುರಂಗಗಳ ಸಂಖ್ಯೆ ಬಿಲ ಗುಣಲಕ್ಷಣಗಳನ್ನು ಚಿಗುರುವುದು ರಿಂದ ಕ್ಷೇತ್ರ ಇಲಿಗಳು ಜಾತಿಗಳ ಲೆಕ್ಕಿಸದೆ ಋತುಗಳಲ್ಲಿ ಕೊಯ್ಲು ಏರಿರುತ್ತದೆ ಬಿ. ಬೆಂಗಾಲೆನ್ಸಿಸ್ ಮತ್ತು ಟಿ ಇಂಡಿಕಾ ಜಾತಿಗಳಲ್ಲಿ ಕಡಲೇಕಾಯಿ ಬೀಜಕೋಶಗಳು, ರಾಗಿ ಕಾಳುಗಳು ಮತ್ತು ಕೆಲವು ಕಳೆಗಳನ್ನು ನಂತಹ ಕೂಡಿಡುವಿಕೆ ವಸ್ತುಗಳನ್ನು ಕಂಡು ಬಂದಿದೆ ಆದರೆ, ಮ್ಯೂಸ್ ಎಸ್ಪಿಪಿ ಮತ್ತು ಬಿ ಇಂಡಿಕಾ ಗಳಲ್ಲಿ ನೆಲಗೂಡುವಿಕೆ ಕಂದು ಬಂದಿಲ್ಲ. ಟಿ ಇಂಡಿಕಾ ಬಿಟ್ಟು ಉಳಿದೆಲ್ಲ ಜಾತಿಗಳಲ್ಲಿ ತರಗೆಲೆಗಳು ಕಂದು ಬಂದಿದೆ. ಕಡಲೇಕಾಯಲ್ಲಿ ಇಲಿ ನಿರ್ವಹಣೆಗೆ ಮುಂಗಾರು ಋತುವಿನಲ್ಲಿ ಕಡಲೇಕಾಯಿಯ ೧೩೮೧ ಕೆ.ಜಿ/ಹೆ ನೊಂದಿಗೆ ಎಲ್ಲಾ ಚಿಕಿತ್ಸೆಗಳ ಪೈಕಿ ಮೊಳಕೆ ಹಂತದಲ್ಲಿ ಶೇ. ೨ ರಷ್ಟು Zn_3P_2 ನ್ನು ಪೆಗ್ ಗಳ ಹಂತದಲ್ಲಿ $Al_2(PO_3)_2$ ದ ಸಿಂಪರಣೆಯು ಅತ್ಯಂತ ಪರಿಣಾಮಕಾರಿ ಎಂದು ಕಂದು ಬಂದಿದೆ. ಅದೇ ಕ್ರಮವಾಗಿ ಬೆಸಿಗೆ ಋತುವಿನಲ್ಲಿ ಪ್ರತಿ ಎಕರೆಗೆ೧೩೫೧.೩೩ ಕೆ.ಜಿ ಇಳುವರಿಯೊಂದಿಗೆ ಕಡಲೆಕಾಯಿ ಶೇ. $Zn3P_2$ ಚಿಕಿತ್ಸೆಯ ನಂತರ ಮೊಳಕೆಯ ಹಂತದಲ್ಲಿ ಪೆಗ್ ರಚನೆಯ ಹಂತದಲ್ಲಿ $Al_2(PO_3)_2$ ದ ಸಿಂಪರಣೆಯು ಅತ್ಯುತ್ತಮ ಎಂದು ಕಂಡುಬಂದಿದೆ. ಶೇ. ೨ ರಷ್ಟು $Zn3P_2$ ಚಿಕಿತ್ಸೆ ಹಂತದಲ್ಲಿ ಸಿ: ಬಿ ಅನುಪಾತವು ಬೇಸಿಗೆ ಋತುವಿಗಿಂತ (೧:೩೬.೫೬) ಮುಂಗಾರಿನಲ್ಲಿ (೧; ೩೮.೧೨) ಹೆಚ್ಚಾಗಿ ಕಂಡುಬಂದಿತ್ತು.

ಕೃಷಿ ಕೀಟಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃ. ವಿ. ವಿ, ಬೆಂಗಳೂರು.

ವಿ. ಶಿವಯ್ಯ
(ಪ್ರಧಾನ ಸಲಹೆಗಾರರು)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

I. INTRODUCTION

Rodents are mammals of the order Rodentia, characterized by a single pair of continuously growing incisors on each of the upper and lower jaws which must be kept short by gnawing. Forty percent of mammal species are rodents, and they are found in vast numbers on all continents other than Antarctica. Common rodents include rats, mice, squirrels, porcupines, beavers, guinea pigs and hamsters. Rodents use their sharp incisors to gnaw wood, break food, and bite predators. Most rodents eat seeds or plants, though some have more varied diets. Some species have historically been pests, eating seeds stored by people and spreading disease

Rodents are one of the important vertebrate pests (Advani and Mathur, 1982) directly related to destruction of crops utilized by man and livestock. They have been identified as the most important mammalian agricultural pests at the global level (Cuong *et al.*,2002).The rodents damage causes huge amount of crop losses and food shortages (Amusa *et al.*, 2005 and Fayenuwo *et al.*, 2007) in some parts of the world. Almost all cultivated crops are vulnerable to rodent depredation at some stage of crop growth and maturity. The various rodent species are adapted to feed on tuberous vegetables below the ground, the small sized cereals, the medium sized oil seeds, the larger fruits and vegetables of various kinds, seeds of cocoa, cardamom, cashewnut, arecanut, fruits and nuts of oil palm (Chakravarthy 1993). The various modes of living namely fussorial, nest living and arboreal are all adaptations to the seasonal availability of cultivated and wild foods. They switch over from vegetarian to animal food mostly insects during periods of non availability of crop produce.

Rodents are important pests of groundnut with 30-40 percentage damage to seeds at germination, 6-9 percentage damage at pod maturation and 4-9 percentage damage to mature pods besides their hoarding. The species inflicting damage to groundnut in Karnataka are *Bandicota bengalensis* (Gray), *Tatera indica* (Hardwicke), *Mus booduga* (Gray) and *Mus meltada* (Gray) (Sridhara and Tripathi, 2005).

Groundnut, *Arachis hypogaea* L. is an annual herbaceous plant in the *Fabaceae* family that originated and was domesticated in South and Central America 3,500 years ago. Now it is grown in tropical and warm-temperate regions worldwide for its seeds and their oil. Groundnut, which are high in protein and vitamin B and E, as well as magnesium, manganese, and phosphorus, are eaten raw or boiled and roasted as a snack, and they are cooked in a wide variety of southeast Asian, African, and South American dishes (ranging from soups, stews, and curries to the peanut and various Asian noodle dishes), as well as used in confections. The seeds, pods, and whole plants are also a source of animal fodder, fibre for paper production, and a green manure. Total commercial production of groundnuts worldwide is 37.6 million metric tons, harvested from 24.1 million hectares. Groundnut is the major oilseed crop of India. It accounts for around 25 per cent of the total oilseed production of the country. Regional estimates are Gujarat (1-3.5 mt), Tamil Nadu (1mt), Andhra Pradesh (1-2mt), Karnataka (0.5 mt), Maharashtra (0.5 mt) are the major producers of groundnuts. India holds the largest acreage (6.7 mha) in Asia (Rao, 2011). In Karnataka area under groundnut cultivation and average production is 0.2 m ha and 0.5 mt, respectively (Manu, 2010).

Field rats make burrows usually on flat lands, on hill sites, field bunds, rail road embankments etc. The rats use these burrow as safety retreats for rest and shelter during adverse weather, for occasional storage of food and rearing young ones. Besides, burrow which is highly diversified harbour various kinds of flora and fauna (Sridhara, 1992).

Several traditional, modern approaches and methods of rodent control are being used for rodent management. Measures to control rodent pests are varied, diverse, traditional, historical and conventional. They can be physical, mechanical, chemical, biological and ecological. Considerable variations exist in the susceptibility of the rodent species to different methods, particularly to rodenticides and trapping, their field applicability, efficacy and economics in different crops, seasons and geographical regions, behavioural responses of the rodent species to these methods in different ecological conditions and their adoption by farmers in different regions of India. Environmental and cultural techniques, such as clean cultivation, proper soil tillage and crop scheduling, barriers, repellents and proofing which may reduce rodent harbourage, food sources and immigration have long lasting effects but are seldom adopted. Rodenticides, which provide an immediate solution to the rodent problem, form the major component of rodent control strategies in India. Poison baiting of rodents with zinc phosphide and burrow fumigation with aluminium phosphide are common in agricultural fields and recently coumatetralyl, bromadiolone and brodifacuum have been introduced for the control of both agricultural and commensal rodent pests in India (Tripathi, 2007).

A good deal of work on insect pests has been done on groundnut in many parts of India. However, very little is known about rodent's infestation in groundnut and the information on burrowing habit, hoarding behavior, breeding and the faunal association in the burrows of rats in India. Therefore, it was considered necessary to study these aspects in detail under field conditions with the following specific objectives.

1. To study the burrow pattern of important field rodents in groundnut field.
2. To study the damaging and the hoarding habits of the field rodents during cropping and post harvest season.
3. The evaluation of rodenticides and snap traps under field conditions for the management of rodents.

II. REVIEW OF LITERATURE

Of all the vertebrate pests, rodents are the most successful causing considerable damage to almost all the cultivated crops throughout the world and undoubtedly quality for the status of conventional pests. Rodents are the largest order of mammals comprising more than 2000 species. An attempt was made to review on burrow pattern, damaging and hoarding habits of field rats and evaluation of rodenticides and traps for the management of rats has been presented here.

The largest family, Muridae, order Rodentia, is represented in India by about 21genera, 50 species and 152 sub-species comprising hamsters, gerbils, rats, mice, bandicoots, etc., grouped under four sub-families (Biswas and Tiwari, 1969).

As per recent records by Pradhan and Talmale (2011) Indian rodent taxa includes 103 species of rodents and 89 subspecies under 46 genera belonging to 7 families.

2.1 Species composition of rodents

Prakash (1975) revealed that the species composition of rodents varies from one habitat to another because of their habitat specificity. The relative abundance of rodent species (rodent associations) may vary with soil types, seasons, irrigation facilities and other ecological conditions of different locations.

Sudden multiplication of rodents and their population assuming menacing numbers, happened in Gujarat state during the year 1975-76 (Shah,1979) and again in 1989-90 (Anon., 1990).

In a study conducted in groundnut growing areas of Gujarat, *Bandicota bengalensis* was found to be the predominant species with 40 to 60 per cent followed by either *M .meltada* or *T. indica* (Anon., 1990).

According to Yiggit *et al.* (2001) *Tatera indica* ranges from northern Arabia throughout the Indo Malayan region. This species commonly known as the Indian gerbil, was first recorded from southeastern Turkey and the species composition of genus *Tatera* increases with desert areas.

Colangelo (2005) indicated that *Tatera indica* were widespread in the sandy plains, grasslands and savannas of the sub-Saharan Africa, Near East, Middle East and the Indo-Pakistan subcontinent and cause considerable agricultural damage to crops.

A survey conducted by Prodip and Parimal (2012) on rodents in Assam revealed that house mouse, *Mus musculus* was found both in and outside of houses, garden in vegetable garden. *Mus booduga* was found commonly in the places of fruit plants near the residence. *Rattus rattus* was found in human residential premises and storage in upland area near agricultural fields that looks like heap of soil. *Bandicota bengalensis* and *Bandicota indica* were found to be the most abundant in rice as well as in sugar cane fields.

2.2 Burrow pattern of important field rats

2.2.1 Lesser bandicoot rat, *Bandicota bengalensis*

Prater (1971) reported that *B. bengalensis* entrance hole of burrows leads to a circular chamber 60cm below the surface and the burrow galleries were extended up to 18m. On bunds burrows were not found to be extensive and burrows found on open grounds were very extensive.

Durairaj and Guruprasad (1975) revealed that the architecture of burrows of lesser bandicoot rats in paddy fields was of the horizontal type. The vertical depth ranged from 10 to 65cm, length varied from 3.8 to 13.5 m, the number of outlets were 2 to 5 and the diameter of the tunnel was 4 to 10cm.

Rajasekharan and Dharmaraju (1975) conducted studies on the burrow pattern of *B. bengalensis* in the paddy fields and reported that the average length of the burrow was 5.76 m, the average diameter and number of openings were 7.45 cm and 4 cm respectively. The average depth was 9.99 to 21.1cm and the number of bed chambers in a burrow was two with the size ranging from 7.5 X 10.0 cm to 30.0 X 45.5 cm. They further reported that the diameter and minimum depth were found to be 6.25 cm and 7.5 cm, respectively irrespective of the type of soil.

Bhaduria and Mathur (1993) found that average length, breadth, depth and diameter of burrow openings of *Bandicota bengalensis* were 508.1, 231.5, 62.2 and 7.6 cm, respectively. Similarly, other structures with their average numbers were recorded as brood chambers (1.3), food chambers (3.1), surface openings (5.4), bolt runs (4.9), emergency openings (2.3), and number of rats (2.29) per burrow. Further the species was forming deeper burrows during summers (80.2 cm) and shallow during winters (40.3 cm).

Sood Pankaj and Chand Prem (2007) studied the burrow pattern of *Bandicota bengalensis* in four different crop fields under mid hill conditions of Himachal Pradesh. They found that area covered by the burrow system was maximum (7.39 m^2) in wheat and minimum (4.27 m^2) in paddy fields with surface openings of 17.10, depth of burrow with 18.52 cm and hoarded material with 0.926 Kg and which were maximum in wheat fields as compared to paddy, pea and tomato.

The burrowing characteristics of *Bandicota bengalensis* in wheat fields in Jammu and Kashmir and Pakistan was studied by Maqbool *et al.*, (2011). One hundred and four burrow systems of lesser bandicoots were recorded from nine fields (1.65 ha), one day after harvest of wheat crop. Out of these 70% (n=73) were found in the interior of fields while 30% (n=31) were located on the field dikes. The study revealed that average length, width, depth and diameter of burrows of *B. bengalensis* were 4.13, 1.60, 14.3 and 14.3 cm, respectively and the average depth and diameter of burrow opening were 16.95 and 8.9 cm, respectively. Similarly, the other structures with their average numbers were recorded as burrow openings (2.3), side tunnels (3.0), dead ends (2.0) and food chambers (2.5). Study revealed that the soil porosity, physical structure and water availability influences the burrowing behavior of *B. bengalensis* in Wheat fields.

2.2.2 Indian gerbil, *Tatera indica*

Srivastava (1968b) revealed that, the burrows of *T. indica* were more extensive in barren fields, than in irrigated groundnut fields (in wet months) and vice versa in case of wheat (in dry months).

Goyal and Ghosh (1993) examined the seasonal changes in burrow structure of *T. indica* and *Meriones hurricane* by excavating their natural burrows in the Thar Desert of India. Burrow system of *T. indica* was of a simple 'Y' shaped type with one or two surface openings whereas, *M. hurricane* tend to congregate in complicated and extensive burrow systems with numerous surface openings. *T. indica* showed a seasonal shift in maximum burrow depth, i.e. from 35cm in winter to 45-50cm in summer. *M. hurricane* did not exhibit any seasonal change in burrow depth.

According to Yiggit *et al.,* (2001) *Tatera indica* prefers uncultivated arid and semi-arid habitats with soft soil and dry river slopes and the burrows had 2- 3 entrances with 10-13 cm in diameter and establishes small colonies in its territory.

2.2.3 Common Indian field mouse, *Mus booduga*

Chandrahas (1974) revealed that, *Mus booduga* inhabits in shallow burrows with only one or two openings; the main opening is sometimes plugged with earth. The mean number of mice per burrow was about 3.3.

Idris *et al.* (2002) observed that *Mus booduga* created long (30-90 cm) burrows with small (2.5-3.75 cm in diameter) openings in Thar deserts and they also noticed that this species usually explore the area before feeding.

Sunita *et al.* (2009) reported that, in Northern India which experiences great variation in climatic condition between summer and winter, burrows of *M. booduga* have an average depth of 41 cm, as against 30 cm in southern India with less climatic fluctuation.

2.2.4 Brown spiny mouse, *Mus platythrix*

Chandrahas (1974) observed that *Mus platythrix* sometimes occupies the burrows deserted by other rodents and make it peculiar by their pebble collection behavior around the surface openings which makes identification simple.

Malhi *et al.* (1987) studied the burrowing and pebble collecting behaviour of *Mus platythrix* and recorded its abundance from sandy and gravel plains as well as rocky habitats. In addition they found that this species used pebbles of different size in brood and bed chambers as well as blocking tunnels and also found that the mean length of the burrow was 295 cm with 1-3 surface openings.

2.2.5 Larger Bandicoot rat, *Bandicota indica*

Arjunwadkar and Gadgil (1974) made studies on the burrow system of *Bandicota indica* in general and reported that a single burrow had 3-4 openings, with a diameter of the tunnel as 8-15 cm and also found that burrow system of was organized in colonies of up to fifteen burrows and openings of burrow were very large and a single burrow system may spread over 300 m^2.

Burrow systems of *B. indica* range from short tunnels (to 72 cm) used as feeding retreats, through to elaborate and extensive complexes with multiple chambers and entrances (Chakraborty, 1992).

2.2.6 *Rattus spp.*

Chandrahas and Krishnaswamy (1974) excavated the burrows of *R. meltada* and in each burrow found 1.86 (July) to 4.23 (December) animals with an average of 2.7 per burrow.

Barnett and Prakash (1975) recorded that the burrow openings of *R. meltada* which were often under bushes. They live in pairs or in small colonies with varied habitat of irrigated fields, bunds, clear patches, hedges and grasslands. In South India it lives in the cracks formed in the irrigated fields by drying of the moist clay.

Chattopadhyay *et al.* (2010), conducted studies on burrowing pattern and damage caused by *Rattus rattus* at the Gangetic and non Gangetic plains of West Bengal, India. In both the regions minimum number of burrow openings were 4 and maximum number were 6 per burrow. The mean diameter of burrow opening was about 7.62±3.32 cm. the depth of burrow in the non Gangetic plain was 27.305±9.884 cm while in Gangetic plain it was about 40.321± 5.396 cm. The average length of burrow to its long axis in the Gangetic plain was 420.00±67.66 cm, and 145.84±106.19 cm in the Non Gangetic plain.

2.3 Important field rodents in groundnut and their damage

Mithal (1987) observed that rodent damage in groundnut occurs from the sowing stage to harvesting of crop both in *Kharif* and *summer* seasons. After the sowing of groundnut crop, the rodents come to sown area, dig out the seeds and consume them. Dominant species found in groundnut field was *Bandicota bengalensis* especially in south India. The loss was comparatively more when there was less rain and field was in a dry condition after sowing operation. If the rains continue for longer time after sowing of the crop, the seed/seedling damage by the rodents decreases due to water logging of the field. Later on, field rodents damage the groundnut crop by cutting the branches and remain in the burrows on the bunds.

Prakash and Mathur (1987) reported that the percentage loss in groundnut due to rodents varied from 4.1 to 25.8 in India and the study also revealed that *Rattus meltada, Tatera indica, Mus musculus* and *Mus booduga* were found damaging the groundnut fields in India.

According to Parshad *et al.* (1987) rodents reduced groundnut yield by an average of 3.86 per cent, a loss of 190.18 rupees per ha. Under sporadic conditions rodents cause a maximum of 18.97 per cent reduction in groundnut yield.

Mittal and Vyas (1992) observed that the population of field rodents and damage due to them increase when the unthreshed groundnut crop was kept in field for drying after its harvest. At this time rodents feed on groundnut pods or store them in the burrows for their future need.

Parshad (1999) reported that the analysis of the information available on the damage and economic losses caused by rodents in rice, wheat, sugarcane, maize, pearl millet, sorghum, oil seeds like groundnut, legumes, horticultural crops, forest species, poultry farms and rural and urban dwellings and storage facilities clearly showed that chronic damage ranging from 2 to 15 per cent persists throughout the country and severe damage sometimes even up to 100 per cent loss of the field crop.

In Karnataka, 30-40% seedlings of groundnut were damaged by rodents and infestation was higher at peg formation (2% damage) and a few percentages during harvesting stages, and the study reported that *Bandicota bengalensis* was the predominant species followed by *Tatera indica* (Sridhara, 1999).

Ram Manohar (2001) reported that, farmers from Gujarat avoid interculturing operation after peg formation in groundnut, this undisturbed condition of the groundnut field enhanced the rodent activity and at the same time crop canopy also plays an important role as it provides shelter to them. Thus, the activity of field rodents increases after pod formation in groundnut and was found at a maximum level at pod maturity stage of crop.

Tripathi (2007) studied on pestilence of rodents in stores and go downs of pulse and oil seed storing area in NEH region (Assam) and observed the occurrence of five species viz., *Rattus rattus* (32%), *Bandicota bengalensis* (29%), *M. musculus* (21%), *R.s sikkimensis* (45%) and *R. norvegicus* (12.8%) in urban areas and four rodent species viz., *R. rattus* (41%), *B. bengalensis* (25%), *M. musculus* (25%), *R. sikkimensis* (9%) from rural storage system.

In oilseed growing areas of West Bengal, the crops were badly infested by various types of rodents. Among them Indian house rat, *R. rattus* was quite preponderant followed by field mice, *M. musculus*, Norway rat, *R. norvegicus* and Indian mole rat, *Bandicota sp.* (Kalyan and Chanchal, 2008).

Singla and Babbar (2010) reported 10.19-42.62 per cent rodent damage in six villages of Ludhiana, Nawan Shehar and Patiala districts. Pre-harvest rodent damage to rice crop in 13 villages of five districts of Punjab varied from 0 to 2.16 per cent with yield loss up to 57.20 ± 32.50 kg per ha.

Rajashekhar (2012) observed the maximum per cent rodent damage (7.12±1.26) during grain filling stage followed by harvesting (5.71±0.80) and booting stage (4.15±1.55) of the ragi crop whereas in soybean the maximum damage was recorded during pod formation stage (6.38±0.43) followed by harvesting (4.88±0.44) and flower and pod formation (4.13±0.41) stage of the crop.

2.4 Hoarding behaviour

Singh *et al.* (1965) reported that, the loss caused by rats in field crops was realized only when the bunds around wheat and paddy were dug out immediately after harvest. Invariably, 1 to 5 kg of ear heads were stored in the exit holes or in brood chamber of the rat burrow.

Deoras (1966) observed 6.6 kgs of hoarding of ground nut from 30 burrows of *B. bengalensis* in Bombay. Srivastava (1968) reported that, *Tatera indica cuvieri* hoarded less quantity of food grains, which ranged from 0.01 to 4.104 kg in groundnut fields.

During pre harvesting and post harvesting periods the rodents destroy tillers of crops and store them within the hoarding chambers of the burrow and observed 4.6-5.4 per cent rice and 11.9 per cent of wheat loss due to rodent damage (Srivastava, 1970). Roy (1974) reported that *B. bengalensis* stored in their burrows at least 5.7 per cent of the total production of grains in the paddy fields.

A study conducted by Chakraborty (1975) on the hoarding behaviour of *B. bengalensis* revealed that the hoarding was more evident in the field than in the store houses. The hoarded materials other than food grains included grass stems, leaves of paddy plants, pieces of cloth and paper. It is also observed that in a few deserted burrows a good amount of stored grains were found. A mean weight of 3.12 kg of paddy was recovered from each burrow system.

Greaves *et al.* (1975) observed that when burrows in a field of 0.118 hectares were completely excavated, 11.1 kg of paddy stored in chambers, 25-100 cm below the surface of ground was recovered while Sridhara *et al.* (1979) excavated burrows and found that each *Bandicota bengalensis* hoards 17.1 g of groundnut pods per burrow on an average during cropping season at Bangalore.

Sridhara and Srihari (1980) conducted studies on food hoarding behaviour of *Tatera indica cuvieri* and found that only maize was hoarded amongst cereals, while the order of pulse hoarding preference was groundnut > cowpea > green gram. They also concluded that larger grains were preferred for hoarding. Patel and Nayak (1987) revealed that the studies carried out from 1983 to 1985 in Junagadh, Gujarat indicated that groundnut pods were hoarded to the extent 320 g per burrow by the *Bandicota bengalensis*.

Ahmad *et al.* (1994) from Bangladesh reported that stored food losses based upon the numbers of small mammals found in farm structures and the amount of stored paddy they potentially could consume or contaminate. It was found that this approximated to 50 kg of paddy per farm family per year. This amount of paddy represents about 5 percentage of the average 1000 kg stored by the farm families over a crop season.

The food hoarded material per burrow system of *Bandicota bengalensis* in wheat fields was 0.478±57.9 kg which is equaled 660±179 ear heads recovered per burrow and the percentage burrow containing food caches was 100 (Maqbool *et al.*, 2011).

2.5 Population dynamics and breeding behaviour

2.5.1 Population dynamics

Sood and Ubi (1975) reported that, 57 murids including 47.36 per cent *M. meltada* followed by *M. musculus*, *M. booduga*, *T. indica*, and *B.*

bengalensis 31.57, 10.53, 8.77 and 1.75 per cent respectively were present at the seedling stage of the groundnut crop in Ludhiana. They further reported that the seedling stage of the crop was highly infested by rodents in the second week after sowing. At the crop growth stage there was a moderate density of rodents, while it reached a higher level at the maturity stage of the crop. At this stage, 71 murids, 30.3 *M. meltada*, 20.2 *M. musculus*, 11.5 *M. booduga*, 6 *T. indica* and 3 *B.* bengalensis were also recorded.

Hopf *et al.,* (1976) reported that ground nut crop was attacked by a number of rodent species in India. Those include *Bandicota bengalensis, Millardia meltada, Tatera indica, Rattus rattus, Mus booduga* and in Tamil Nadu unspecified squirrels also attack groundnut crops. Rana and Advani (1981) had observed the peaks in the numbers of *R. meltada pallidior* during winter in the crop fields of south-eastern Rajasthan.

The soft furred rat, *Millardia meltada* was the predominant species at Madhya Pradesh with the first peak (6/25 traps) during the third week of august and the second peak (15/25 traps) at the beginning of the maturity stage of the crop during *Kharif*, 1983. During the entire crop season the trapped males outnumbered the females and the overall sex ratio was 67.3:32.6 (Anon., 1984).

Parshad *et al.* (1987) conducted a study around Ludhiana (Punjab) and revealed that 13.9 *Mus spp.*, 6.5 *B. bengalensis*, 4.2 *T .indica* and 4.2 *R. meltada* per100 traps per day in irrigated fields of Ludhiana (Punjab), whereas 17.5 *Mus spp.,* 15.0 *T. indica* and 7.5 *R. meltada* were trapped per 100 traps per day from non irrigated fields. Srinivas Rao and Nanda Kishor (2009) reported that, the population size *of B. bengalensis* was higher during vegetative growth stage of rice crop in both *Kharif* and *Rabi* seasons. Sex ratio of *B. bengalensis* showed monthly variation in relation to crop growth period and it was highest during November. The species remained found throughout the year with higher reproduction activity during the reproductive phase of the crop. The rodent density was observed throughout the year and it ranged from 14 to 33 live burrow count per ha at Mandya, Karnataka. The predominant species found was *T. indica* followed by *M. booduga* and *B. bengalensis*. In soybean field the rodent density was found from sowing to harvesting stage and it was ranged 3 to 18 LBC per ha and the predominant species found in order were *B. bengalensis* > *M. booduga* > *T. indica* (AINP, 2010).

The number of rodent burrows per ha ranged from 12.50 ± 3.15 to 110.55 ± 28.52 in wheat and rice crop fields of 15 villages of Punjab (Singla and Babbar 2010). On the basis of live burrows, *B. bengalensis* was the predominant species in Patiala, Hoshiarpur and Kapurthala districts and *M. booduga* and *T. indica* were predominant rodent species in Muktsar and Mansa districts, respectively.

In cumin the rodent-burrow density was lower (7-22 burrows/ha) in the field than in the surrounding fallow land (56-87 burrows/ha). During germination and further vegetative growth up to the flowering stage, rodents from the surrounding fallow land established their population in the crop-field mainly in the peripheral regions, recording a burrow-density of 50-75 burrows per ha at 15 days after sowing. However, at maturity, when irrigation and other inter-cultural operations were resumed, the central portion of the field was also infested with rodents, recording a burrow-density of 20-35 burrows per ha (Chaudhary and Tripathi, 2010).

2.5.2 Breeding

2.5.2.1 *Bandicota bengalensis*

Rajasekharan and Dharmaraju (1975) observed that *B. bengalensis* breeding in rice fields of Andhra Pradesh takes place only twice in a year, October-December and April- May, coinciding with maturity period of first and second phase of the crops of rice.

Roberts (1977) observed in southern Pakistan that the largest litters were born from September to November, while during the remainder of the year usual litter size is 5 to 10.

Mohan Rao (1979) studied that after a natural disaster and decline in the population, breeding potential increases considerably by having larger litter size.

Bandicota bengalensis had two seasonal peaks of breeding i.e. September –October and January- March (Srihari and Govinda Raj, 1988).

Parshad (1987) observed that percentage of pregnant females of *Bandicota bengalensis* in the population remains considerably high almost in all the months but it was found maximum during November.

2.5.2.2 *Tatera indica*

Prasad (1961) and Govinda Raj and Srihari (1987) reported that breeding season of *Tatera indica cuvieri* was September to early March (less in December) in Bangalore, India.

According to Jain (1970) pregnant females of *Tatera indica* were found every month of the year with annual average being 29.7 per cent and maximum littering were observed during August and also in February when it starts warming up after the winter season.

2.5.2.3 *Bandicota indica*

Bandicota indica breeds round the year in West Bengal while in Andhra Pradesh breeding is restricted to September-March (Chakraborty, 1985).

Aplin *et al*. (2003) revealed that, breeding activity in natural marshland habitat on Sagor Island, off the coast of India, found breeding in all months of the year. The overall adult pregnancy rate was 27 per cent, but this peaked at 50 per cent in October–April and fell to 10% in May–September. Mean litter size did not vary between months.

Tithiparamote (2009) experimented that, pregnancies of *Bandicota indica* occurred predominantly in wet season with the male tended to have heavier testis. But they also observed sperms in males during dry season.

2.5.2.4 *Mus spp.*

Rao *et al*. (1977) observed that, the reproduction activity in *Mus spp*. characterized by rapid sexual maturation, short gestation period, postpartum estrus, polyestrous breeding throughout the year.

Mus booduga breed in all months of the year In Kerala. Pregnancy rate averaged through the entire year is around 20%, but there is a peak in pregnancies (to >70% of adult females) during the monsoon season. Estimates of litter size range from 1-6 to 6-13 (Bhat and Sujatha, 1991).

Govinda Raj (1994) revealed that, *Mus platythrix* exhibited active breeding during the period June to February followed by sexual quiescence during the period March to May. The peak reproductive activity was seen during September (55%), October (79%) and November (62%) coincided with peak abundance of heavier males and females in the population. A litter size of two (during June) to eight (during October) also coincided with peak prevalence of pregnancy.

Breeding season of *Mus booduga* coincided with the harvesting of major crops, namely, rice and wheat. In southern India, where the difference in climatic conditions in summer is less-marked compared to other seasons, and availability of the crops is fairly continuous, breeding was observed almost throughout the year (Sunita *et al.*, 2009).

2.6 Management of rodents

According to Deoras (1966) a control operation reducing the population of rodents to 5-10 percent of its original level is considered to be a fair success.

2.6.1 Traps

Mukthabhai and Majumder (1989) observed that, glue traps were quite effective in controlling the population of roof rats in stores, ware houses and go downs and also found that a single glue board caught 8 – 11 adult *Rattus rattus* when placed continuously for 5 days.

Puangtong and Greangsak (1998) revealed that, the bow traps could be a suitable alternative method for controlling rodents in soya bean fields. This could reduce 35.30 per cent rodenticide used for rodent management in soya bean crops in dry season followed by bow traps and 1per cent zinc phosphide bait.

2.6.2 Chemical rodenticides

According to Mann and Bindra (1974) the baits treated with 2 per cent zinc phosphide have caused a reduction of 84 to 93 per cent reduction of field rodents in wheat fields.

Romero *et al.* (1978) revealed that a control demonstration combat was carried out at one of the experimental stations with a bait prepared with a two per cent zinc phosphide in a place where it had been previously determined there was a population of 39 rats per hectare, which represents an efficiency of 53.85 per cent.

Sridhara and Krishnamurthy (1979) achieved 73 per cent reduction of rodents by using of two per cent zinc phosphide in paddy fields at Mandya, Karnataka.

Two acute rodenticides, zinc phosphide and vacor, at different concentration were tested on the rice field rats, *R. argentiventer* and the bandicoot rats, *B. indica* with a choice feeding procedure by Kasem (1980). It was found that zinc phosphide at 0.50, 0.80 and 1.60 per cent caused 30, 30 and 60 per cent mortality, respectively, to *R. argentiventer* and at 1.60 per cent caused death only 30 per cent to *B. indica*, whereas vacor at 0.50, 0.80 and 1.60 per cent caused 70, 60 and 80 per cent mortality of *R. argentiventer* and killed 60 per cent of *B. indica*.

Mathur and Prakash (1981) experimented that second generation anticoagulant rodenticides especially brodifacoum were highly effective against agricultural and commensal vertebrate pest like *T. indica, M. hurriane* and *Rattus rattus*.

Chopra and Sood (1983) reported that, among the different treatment combinations, 2% poison bait of RH-787 followed by fumigation with aluminium phosphide as a follow-up action was the most effective against field rodents in groundnut as it resulted in reducing 95.50 per cent of rodent activity.

Among two different rodenticides applied in groundnut fields, zinc phosphide (2.5%) bait was found to be more effective as it caused 82 per cent reduction in rodent activity, whereas brodifacoum (0.005%) bait reduced 69 percent of the rodent population in a Punjab (Anon.,1984).

Advani (1986) revealed that the application of brodifacoum (0.005% and 0.002%), bromadiolone (0.005% and 0.002%) and warfarin (0.025%) reduced rodent populations by 74.50, 73.58, 79.10, 69.16 and 68.44 per cent, respectively, resulting in reduction of rodent damages to nuts by 74.93, 70.26, 78.24, 69.53 and 61.90 per cent, respectively. However, brodifacoum (0.005%) impregnated with rice and coconut oil controlled rodents by 86.88 per cent with reduction in damages by 82.85 per cent. It was followed by bromadiolone (0.005%) mixed with rice and coconut oil giving 86.48 and 83.33 per cent control of rodents and damages, respectively. Except in the case of brodifacoum (0.005%), where pulse baits followed the order of rice > ragi > pulse, whereas, coconut oil proved to be best attractant followed by groundnut oil and palm oil.

Parshad *et al.* (1987) reported that, a single treatment with poison bait at 80 to 90 days after planting with 2.4 per cent zinc phosphide, 0.005 per cent brodifacoum and 0.005 per cent bromadiolone in cereal baits at the rate of one kg per ha resulted in 58.07, 42.26 and 40.88 per cent rodent control, respectively, in non irrigated groundnut fields. In irrigated fields, 58.70 and 67.02 per cent rodent control was achieved with zinc phosphide and brodifacoum baits, respectively. Significantly higher rodent control was obtained with two treatments of either brodifacoum or bromadiolone than with a single treatment of any rodenticide. Also reported that a single baiting with 2.4 per cent zinc phosphide, 0.005 per cent brodifacoum and 0.005 per cent bromadiolone in cereal baits resulted in about 58, 42 and 41 per cent rodent control, respectively in non irrigated fields. However, in irrigated groundnut fields, 58 and 67 percent rodent control was achieved with zinc phosphide and bromadiolone baits, respectively.

Narendra Kumar (1988) reported that, *Bandicota indica* was controlled up to 83.33 per cent by zinc phosphide baits, whereas single grid baiting with zinc phosphide followed by a baiting with brodifacoum or double baiting with brodifacoum or bromadiolone resulted in 89-93 per cent rodent mortality in wheat fields (Ahamad and Parshad, 1989).

The highest burrow control success (85.92%) was achieved nine days after treatment in repeated baiting with bromadiolone. Further, maximum yield of groundnut pods was recorded in bromodiolone (1500 kg/ha) treatment, though statistically it was at par with cholecalciferol and flocoumafen (Anon., 1990; 1991).

Rodents damaged 6.32 to 8.15 per cent wheat tillers in three districts of Himachal Pradesh, *viz.* Kangra, Sirmour and Solan. Maximum damage was recorded when the crop was at maturity stage. Two treatments of 2.5 per cent zinc phosphide at 45 days interval significantly reduced the damage from 7.16 per cent to 1.25 per cent in the experimental fields, thereby increasing the yield of grains by 56 kg per ha (Sheikher and Jain, 1991).

Mittal and Vyas (1992) observed that, the rodent control can be brought out by the methods of poisoning by use of acute and chronic poisons, fumigation, trapping, use of repellents and environmental control in groundnut crop.

Parshad (1999) revealed, that the poison baiting of rodents with zinc phosphide and burrow fumigation with aluminium phosphide were common in agricultural fields and recently racumin (coumatetralyl) and bromadiolone have been introduced for the control of both agricultural and commensal rodent pests in India.

Staples *et al.* (2003) reported that, among the acute rodenticides, zinc phosphide is widely used because it is acceptable to most of the rodent species, relatively safe to non-target species and does not have any known residual effect in crops, soil, water or the atmosphere. Moreover, zinc phosphide causes emetic effects in most mammals, birds and reptiles (Hood, 1972). By contrast, in rodents, zinc phosphide like other potential emetics, cannot be eliminated by vomiting or regurgitation. Second generation single dose anticoagulants such as brodifacoum (Dubock, 1980 and Parshad *et al.*, 1987) and bromodiolone (Marsh, 1977) at 0.005 per cent in cereal bait have been tested extensively against rodents in both the laboratory and the field in India and several other countries (Parshad, 1999). These poisons were effective at low doses, require 1 to 2 days of feeding to achieve cent per cent mortality of rodents, and they do not affect poison bait acceptance. As per Butani (2006), both the acute rodenticide, zinc phosphide (2%) and second generation anti coagulant bromadiolone (0.005%) effectively controlled rodents in groundnut fields.

Khan (2007) conducted a field study to evaluate the effectiveness of formulated baits of 0.005 per cent brodifacoum, 0.0375 per cent coumatetralyl, 0.005 per cent bromethalin and 2 per cent zinc phosphide against field rats inhabiting sugarcane crop. After five applications of baits, the rodent activity reduced to 90 to 96 per cent except for zinc phosphide treatment where in it reduced to 76.04 per cent. The counts of damaged canes on treated plots varied from 1.10-2.50 per cent, while on non-treated plots, the damage ranged 13.0-29.9 per cent. Yield of cane significantly increased (26.64-32.92%) on three treated sites except on zinc phosphide site where cane yield increased by 9.89 per cent.

Tripathi (2007) revealed that the treatment of sugarcane crop fields with bromadiolone (0.005%) at 800, 1600 and 3200 g per acre during February yielded a rodent control success of 58, 67 and 70 per cent, respectively. The treatment in sugarcane fields also saved a rodent damage of 2.56 per cent in the surrounding wheat crop fields at pre harvest stage. In case of groundnut, double poison baiting with zinc phosphide followed by bromodiolone (0.005%) during first week of August and consequently in second week of September was most effective yielding 89.00-91.70 per cent control success with net profit of Rs. 2461.5 per ha.

After fumigating the burrows with aluminium phosphide 1.5 g tablets indicated a control success of 86 per cent while census baiting method showed 85.6 per cent. While fumigation of burrows with 2 tablets each indicated a rodent control success of 75.3 per cent with burrow count method, census baiting method exhibited a control success of 74.6 per cent against *B. bengalensis* in the rice fields (Kumar *et al.*, 2009).

Khan *et al.* (2009) evaluated the efficacy of 0.005% flocoumafen, 0.0375% coumatetralyl and 2% zinc phosphide for small rodents infesting groundnut fields in the Pothwar Plateau, Pakistan. Study revealed the reduction of rodent activity by 70.2% for zinc phosphide, 90.4% for flocoumafen and 95% for coumatetralyl. It also showed that yield of groundnuts, obtained only from the flocumafen and coumatetralys treated plots, were substantially increased 61.6% and 59.2%, respectively.

Single application of Zn_3P_2 (2%) in paddy fields at Mandya district, Karnataka performed better with 72.29 per cent reduction in damage and 75 per cent reduction in population. While the Aluminium phosphide (6g @ 1 tab/burrow), 2 per cent bromodiolone baiting (0.25% CB) and bromodiolone cake (0.005% Rb) performed equally among themselves with per cent reduction in damage and per cent reduction in population ranging from 62.76 to 66.96 and 63.00 to 65.38, respectively (AINP, 2010).

Neena and Parshad (2010) reported that, the rodenticide treatment may be applied either by double-baiting with 2 per cent zinc phosphide followed by bromadiolone (0.005%) after 15 days at one kg per ha each or by single-baiting with bromadiolone (0.005%) at two kg per ha to protect the sugarcane crops of Punjab from rodent damage during the months of December-January. The impact of rodenticide treatment in cane fields was also evident in the adjoining wheat crop fields where the incidence of rodent damage was less (0.97-3.24%) than in the fields surrounding untreated cane fields (3.53-6.22%).

Neena *et al.* (2010) studied the efficacy of acute and anticoagulant rodenticides in sugarcane fields and the results revealed that, to protect the sugarcane crop from rodent damage during the months of December-January, the rodenticide treatment may be applied either by double-baiting with 2% zinc phosphide followed by 0.005% bromadiolone after 15 days at 1 kg per ha each, or by single-baiting with 0.005% bromadiolone at 2 kg per ha.

Rajashekhar (2012) reported a reduction of 67.15 per cent in rodent population by zinc phosphide baiting in soybean field with broken jowar and 73.76 per cent with broken ragi while in ragi field it was 63.98 and71.43with broken jowar and broken ragi for baiting, respectively. Further the per cent reduction in damage was 4.62 and 5.43 by poison baiting with broken jowar and broken ragi respectively in ragi field and in soybean field it was 4.49 per cent and 4.65 per cent, respectively.

2.7 Cost Benefit Ratio

Frank (1970) reported that the rodent control in sugarcane gives a cost: benefit ratio of approximately 1:5. Khan (1977) estimated a 1:36 C: B ratio with zinc phosphide while, more expensive coumatetralys treatments gave a return of 1:11 in Pakistan.

Advani *et al.* (1981) revealed that in millet, management of about 90 per cent of rodent populations resulted into cost: return ratio of 1: 267 whereas, the estimated cost and benefit ratios of 1:247 in rodent control in wheat using different rodenticides (Advani *et al.*, 1982). The C: B ratio was 1:900 in some vegetables in the Rajasthan desert for rodent management (Advani and Mathur, 1982).

Ahamad and Parshad (1987) recorded that the estimated cost and benefit ratios of 1: 8 to 1:25 in sugarcane for rodent control with different rodenticides and it was 1:26 to 1:38 in wheat field (Ahamad and Parshad, 1989).

Maximum increase in pod yield over control and the highest net incremental cost benefit ratio (1:48.98) were also recorded in zinc phosphide-zinc phosphide treatment combination (Anon., 1990).

Cost: benefit ratio of 1:11.42 excluding labour worked out for bromadiolone treatment for *R. meltada* control in paddy field of 0.1 ha (Sathisha, 1991) while, Sridhara (1992) reported that, the estimated cost and benefit ratios in rodent control with different rodenticides in paddy were 1:18 and 1:24.

Mittal and Vyas (1992) revealed that, cost and benefit ratio in peanut by chemical control of rodents was 1:49 whereas, in watermelon fields it was 1:66 to 1:90 (Kumar *et al.*, 1997). However by anticoagulants there was more than 20 fold economic returns for groundnut in Pakistan for rodent management (Khan *et al.,* 2009).

Neena and Parshad (2010) estimated that the cost: benefit ratio of double baiting in cane fields as 1:33.72 with 2 per cent zinc phosphide followed by 0.005 per cent bromadialone at 1 kg per ha as compared to C: B ratio of 1:24.45, 1:13.87 and 1:7.44 with 2, 4 and 8 kg per ha of the bait application, respectively.

Rajashekhar (2012) worked out the cost: benefit ratio of 1:4.63 for poison baiting in ragi field with broken jowar and 1:6.74 with broken ragi while in soya bean field it was 1:6.12 and1:8.20 with broken jowar and broken ragi for baiting, respectively.

III. MATERIAL AND METHODS

The study on habitat burrow ecology of field rodents and their management in groundnut is carried out during both during *Kharif* and *summer* of 2012-13 in groundnut crop (Plate No:1) in Thagachuguppey village, Magadi Taluk in Ramanagara District of Karnataka state located in 12.97^0 N 77.23^{0}E with an altitude of 925 m above mean sea level. Major crops cultivated in the area are groundnut and ragi with an average precipitation of 800 mm per annum. The soil type was lateritic.

3.1 Method of study

3.1.1 Identification of burrows

The rodent burrows present in and around the groundnut field were identified based on certain characteristic features of different rodent species as mentioned below.

The lesser bandicoot (*Bandicota bengalensis*) rat burrows revealed the presence of heaps of soil covering the openings located at different points of burrow. Confirmation regarding the presence of rats inside the burrows was done by closing the burrow at one evening and taking observation in next morning. If the closed burrow is opened in next morning then it was considered as live burrow and if the closed burrows remain closed it was considered as dead burrow.

Indian gerbil (*Tatera indica*) burrows were identified by the presence of openings which were almost circular in shape and were always found uncovered externally with or without the presence of loose soil in front of the opening. In order to know the presence of gerbils inside a burrow, a thin flexible stick of about 60 cm length was inserted inside the openings of the burrow and if all the openings were found to be sealed intact with loose earth inside the tunnel openings , then the

Plate 1. A general view of study area

burrow was considered as a live or active burrow. A burrow wherein the tunnel openings were not sealed, it was considered as a dead burrow or a deserted burrow. In addition, the presence of hair of the rats and also the presence of adult tenebrionid beetles near the tunnel seals helped to detect the presence of gerbils inside the burrow.

The burrows of the Indian field mouse (*Mus booduga*) can be distinguished from those of other rodent species by smaller openings of about one centimeter with scooped soil before the burrow opening.

The brown spiny mouse (*Mus platythrix*) exhibits a peculiar behaviour of pebble collection around the surface openings, which made the identification simple.

The large bandicoot rat (*Bandicota indica*) burrows are recognized by the fresh, wet globules of soil and soft faecal matter at the burrow opening. Fresh foot prints and tail marks near burrow also indicators of live burrows.

3.1.2 Excavation of burrows

Burrows were excavated in and around groundnut fields of farmers at different stages of crop (Germination, Peg formation, Harvesting and Post harvesting) both during *Kharif* and *Summer* seasons of 2012-13. Twenty burrows of each species of *Bandicota bengalensis*, *Tatera indica*, *Mus booduga* and *Mus platythrix* were excavated. At each stage five burrows were excavated for all species to study the burrow structure. However in case of *Bandicota indica* only two burrows were excavated in each season during harvesting stage as there is no activity in other periods. While excavating heap of soil was removed and the opening was traced to the ground level with the help of a spade and pickaxe. At places where the soil was hard to dig, a crowbar was used instead of a spade. As the digging operation was on positions of the tunnel openings, side tunnels, nest chambers, food chambers, bolt holes and blind tunnels were marked using wooden pegs. Measurements of the positions marked by wooden pegs were taken with the help of measuring tape. Length, width and depth of the burrows, diameter of the burrow openings, length of blind tunnels, bolt tunnels and diameter of the tunnel were measured. Number of the openings of the burrow, number of the side tunnel, number of the food chambers and different types of hoarding materials in the burrow was also recorded. Presence of litters in each burrow was also taken into consideration and litter size was recorded. The temperature inside the burrow was recorded with the help of soil thermometer. After the excavation, sketches of the burrows were drawn to show the various position of the burrow and photographs of the structure of burrows of different rodent species were taken.

3.2 Hoarding habit

When the burrow was dug, care was taken to collect various types of food materials stored inside the burrows of all the rodent species in the groundnut field. The hoarded grains, ear heads of crops and other materials inside the burrows were collected in a polythene bag and categorized. Weights of the groundnut pods among them were taken using a pocket balance. The presence of flora and fauna in the burrows were also collected and got them identified from the specialists.

3.3 Field evaluation of rodenticides and snap traps for the management of rodents

Fifty acres area comprising of groundnut crop at Thagachuguppey, Magadi Taluk in Ramanagara district of Karnataka state, where burrows of *Bandicota bengalensis*, *Tatera indica* along with other rodent species were evident had been selected for field evaluation of rodenticide.

Treatments were carried out in experimental plots at germination and pod formation stages of groundnut crop in both *Kharif* as well as *Summer* seasons with three replications for each treatment. Each plot of 20 guantas is separated by a distance of 20 m to maintain isolation. Treatments were as following:

T_1: Setting 54 Snap traps per ha at germination stage

T_2: Zn_3P_2 (2%) baiting at germination stage

T_3: Bromadiolone (0.25%) CB at germination stage

T_4: $Al_2 (PO_3)_2$ application at germination stage

T_5: Setting 54 Snap traps per ha at peg formation stage

T_6: Bromadiolone (0.25%) CB at peg formation stage

T_7: Zn_3P_2 (2%) baiting at peg formation stage

T_8: $Al_2 (PO_3)_2$ application in burrows at peg formation stage

T_9: T_1+T_7 (54 Snap traps per ha at germination stage +2% Zn_3P_2 baiting at peg formation stage)

T_{10}: T_3 + T_7 (Bromadiolone (0.25%) CB at germination stage + 2% Zn_3P_2 baiting at peg formation stage)

T_{11}: T_2 + T_8 (2% Zn_3P_2 baiting at germination stage + $Al_2 (PO_3)_2$ application in peg formation stage)

T_{12}: T_2 + T_6 (2% Zn_3P_2 baiting at germination stage + Bromadiolone (0.25%) CB at peg formation stage)

T_{13}: Control

In the selected field the live burrows were identified and counted a day before, seventh and fourteen days after treatment to know the per cent reduction of rodent population in a treated area. To find out the live burrows on the first day all the burrows were plugged with loose soil in the evening and next day morning the burrows which were found open were considered as live burrows and recorded as LBC/ha.

Pre treatments were carried out two days prior to actual treatment for all the treatments except for aluminium phosphide and control. Pre baiting was carried out using the bait without poison for two days at 2kg bait/ ha and snap traps were left in the field without setting for two days to make the rodents to acclimatize for new things or to overcome neophobia.

Treatments were imposed in 20 gauntas field with three replications following RCBD during germination and peg formation stages of crop. In case of snap trap, real setting was carried out on the third day @ 11 traps per plot of 20 guantas for two consecutive days. Snap traps were kept along the borders as well as between rows of groundnut plot. On both the days observations on trapped rodents were taken.

On third day poison baiting was done. The poison bait was prepared by thoroughly mixing rice grains (44 g), ragi grains (44 g), groundnut powder (5 g), groundnut oil (5 ml) and 2 g of poison (zinc phosphide and bromadiolone) in case of poison bait in a plastic container and 10-15 g bait was put in the polythene bag tied with a rope and the same was placed both inside the burrows and bunds applied at the rate of 1kg bait per ha. The burrow were closed after the treatment and the observation on mortality in terms of live burrow count was recorded on the next day in case of Zn_3P_2 application and 7 and 14 days after baiting in both the poison baits treatments. Al_2 $(PO_3)_2$ were applied only in live burrows of field. Before application the burrows were confirmed as live burrows, and then 3 g tablet per burrow was inserted along with a small piece of cotton soaked in water. After that the burrow was sealed with wet mud. Burrows found open after 24 hours were considered to represent the surviving population. Since burrow count is considered as a reliable index of field rodent population (Barnett and Prakash, 1975) and per cent reduction in the live burrows was assumed to represent the per cent population killed.

3.4 Damage by rodents

The germination damage in terms of germination percentage by rodents was calculated as per the following formulae.

$$\text{Germination percentage} = \frac{\text{No. of seeds germinated}}{\text{No. of seeds sown}} \times 100$$

During peg formation stage damage was worked out by the formulae

$$\text{Peg damage (\%)} = \frac{\text{Cut tillers}}{\text{Total tillers}} \times 100$$

Similarly pod damage per cent during harvesting stage was estimated by using the formula

$$\text{Pod damage (\%)} = \frac{b+c}{a+b+c} \times 100$$

Where,

a = No. of undamaged pods

b = No. of scratched pods

c = No. of freshly bitten pods

Pod yield of all the plots were taken separately. Similar experiment was repeated in summer season also and in both the seasons the incidence and yield of treated plot were compared with that of control plot and analysis was carried out as per RCBD procedure. Cost-benefit (C:B) ratio was also calculated to find out a best cost effective treatment.

IV. RESULTS

Results on investigation, carried out during *Kharif* 2012 to *Summer* 2013, on habitat, burrowing behavior, burrowing pattern, hoarding behavior, breeding pattern, damage percentage of different rodents in groundnut field and evaluation of rodenticides for management of rodents are presented in this chapter.

4.1 Rodent species:

The following five rodent species of the family muridae were commonly found in the groundnut fields of study area. The predominant species found was Indian mole rat, *Bandicota bengalensis* (Gray) followed by Indian Gerbil, Tatera *indica* (Hardwicke); Common Indian field mouse, *Mus booduga* (Gray); Brown spiny mouse, *Mus platythrix* (Gray) and Larger Bandicoot rat, *Bandicota indica* (Bechstein). The behavior of each species and their habitat are discussed in detail.

4.2 Microclimate:

Mean temperature inside the rodent burrow was 23.3°C±1.56°C which was less by 3°C compared to the atmospheric temperature of 27.1 ±2.35°C during *Kharif* season (July to November) and during *Summer* (January to April) burrow temperature was 25.3±1.76°C compared to atmospheric temperature of 30.6±3.76°C. But the relative humidity inside the burrow was 87.3±5.67, which was 15 per cent more than outside atmosphere during *Kharif* season and 79±7.22 during summer season which was more than 19 per cent.

4.3 Density of different species of rodents in and around in Groundnut field

Maximum number of burrows of *Bandicota bengalensis* found in harvesting stages of *Kharif* and *summer* season (Table 1). *Tatera indica*

Table 1. Population density of *Bandicota bengalensis* in and around groundnut field

Season	Crop stage	LBC/ha			
		Within field	On bunds	Away from bunds (up to 10m)	Total burrows
Kharif	Germination	0	9	4	13
	Peg formation	3	12	6	21
	Harvesting	6	17	10	33
Post-harvest (Off season)		0	4	11	15
Summer	Germination	0	9	5	14
	Peg formation	4	13	6	23
	Harvesting	9	15	10	34
Post-harvest (Off season)		0	5	13	18

Table 2. Population density of *Tatera indica* in and around groundnut field

Season	Crop stage	LBC/ha			
		Within field	On bunds	Away from bunds (up to 10m)	Total burrows
Kharif	Germination	0	0	9	9
	Peg formation	3	2	11	16
	Harvesting	7	5	16	28
Post-harvest(Off season)		0	1	10	11
Summer	Germination	1	0	9	10
	Peg formation	3	2	13	18
	Harvesting	7	5	18	30
Post-harvest(Off season)		0	1	11	12

Table 3. Population density of *Mus booduga* in and around groundnut field

Season	Crop stage	LBC/ha			
		Within field	On bunds	Away from bunds (up to 10m)	Total burrows
Kharif	Germination	0	3	0	3
	Peg formation	1	5	2	8
	Harvesting	1	7	2	10
Post-harvest (Off season)		0	1	4	5
Summer	Germination	0	3	1	4
	Peg formation	1	5	3	9
	Harvesting	2	6	2	10
Post-harvest (Off season)		0	1	5	6

Table 4. Population density of *Mus platythrix* in and around groundnut field

Season	Crop stage	LBC/ha			
		Within field	On bunds	Away from bunds (up to 10m)	Total burrows
Kharif	Germination	0	0	3	3
	Peg formation	0	1	5	6
	Harvesting	0	2	5	7
Post-harvest (Off season)		0	0	4	4
Summer	Germination	0	0	3	3
	Peg formation	0	1	5	6
	Harvesting	0	2	6	8
Post-harvest (Off season)		0	1	4	5

Table 5. Population density of *Bandicota indica* in and around groundnut field

Season	Crop stage	LBC/ha			
		Within field	On bunds	Away from bunds (up to 10m)	Total burrows
Kharif	Germination	0	0	0	0
	Peg formation	0	0	1	1
	Harvesting	0	0	2	2
Post-harvest (Off season)		0	0	0	0
Summer	Germination	0	0	0	0
	Peg formation	0	0	1	1
	Harvesting	0	0	2	2
Post-harvest (Off season)		0	0	0	0

Table 6. Population distribution of rodent density in and around groundnut field

Season	Crop stage	LBC/ha					Total LBC/ha	Position of burrows		
		Bandicota bengalensis	*Tatera indica*	*Mus booduga*	*Mus platythrix*	*Bandicota indica*		Within field	On bunds	Away from bunds (up to 10m)
Kharif	Germination	13	9	3	3	0	28	0 (0)	13 (46)	15(54)
	Peg formation	21	16	8	6	1	52	7(14)	20 (38)	25 (48)
	Harvesting	33	28	10	7	2	80	14(18)	31 (39)	35 (44)
Post-harvest (Off season)		15	11	5	4	0	35	0 (0)	6 (17)	29 (83)
Summer	Germination	14	10	4	3	0	31	1(3)	12(39)	18 (58)
	Peg formation	23	18	9	6	1	57	8 (14)	21 (38)	28 (48)
	Harvesting	34	30	10	8	2	84	18 (21)	28 (33)	38 (45)
Post-harvest (Off season)		18	12	6	5	0	41	0 (0)	8(20)	33 (80)
Percent distribution		**41.91**	**32.84**	**13.50**	**10.29**	**1.47**	**100**	**11.76**	**34.06**	**54.16**

Note: In bracket represents percentage of burrows

burrows were concentrated away from field and burrow count was more in harvesting stages during both seasons (Table 2). Total burrows were more in harvesting stages of *Kharif* and *summer* in *Mus booduga* (Table 3) and *Mus platythrix* (Table 4). *Bandicota indica* burrows were found only in peg formation and harvesting stages of both seasons (Table 5).

Bandicota bengalensis population in the field is more in all stages and in all seasons with the percentage distribution is 41.91 percent which mainly concentrate on field bunds and that of *Tatera indica* per cent distributions were 32.84 percent and it was concentrated mainly away from field and bunds area which is 20m around the field. *Mus booduga* forms next important species of the area with 13.50 percent population and concentrated mainly on field bunds. *Mus platythrix* comprises 10.29 per cent population and it lies within 20 m distance from field and less frequent within field and on bunds (Table 6).

4.4 Lesser bandicoot rat, *Bandicota bengalensis* (Gray)

4.4.1 Burrowing behavior

The lesser bandicoot rat burrows were clearly marked by the presence of heaps of soil at different points along the burrow length. All the openings were covered completely by the excavated loose soil which was heaped on the surface in the form of soil mounds. The soil mounds appear in the form of “Mole hills”. Careful examination of very large mounds of burrow revealed that two or more adjacent mounds merged to form one composite mole-hill. All the openings were sealed from inside by rat using loose excavated soil. The diameter of the finished mole-hill varied from 13 to 60 cm and the height ranged from 6 to 38 cm. The amount of soil excavated by the bandicoot adults differed from burrow to burrow. The mean weight of the soil thrown out was 5.55±3.1 kg. However, a maximum of 25 kg and a minimum of excavated soil were recorded from two burrows. Excavated soil contained cut roots of grasses and other weed plant roots

4.4.2 Burrow structures

4.4.2.1 Main entrance

Main entrance of the lesser bandicoot rat was difficult to locate. However, the presence of fresh soil heap near an opening of burrow was considered as the main entrance. The mean diameter of the main entrance were 6.29±0.31 and the mean diameter in *Kharif* season were more than summer season which was 6.49±0.44 cm with harvesting stage had highest mean diameter of 6.98 cm and lowest during germination stage with 6.13 cm. The mean diameter during peg formation and post harvest were 6.35 cm and 6.27 cm respectively. Similarly in *summer* season mean diameter 6.19±0.24 cm with harvesting stage had highest mean diameter of 6.43 cm and lowest during germination stage with 5.96 cm. Peg formation and post harvest had an intermediate range with 6.18 cm and 6.09 cm respectively (Table 7) (Plate 2, Plate 3, Plate 4 and Plate 5).

4.4.2.2 Number of openings

The surface openings were externally covered by the excavated soil heaps. The openings were sealed on the surface with the packing of loose soil and packing was not usually hard. The thickness of the earthen seal ranged from five to fifteen cm. The mean numbers of burrow openings were 3.76±1.29 numbers. During *Kharif* season it was 3.69±1.52 with highest during harvesting season (5.01) when the rodent activity was maximum and lowest during germination stage (2.03) when the rodent activity was minimum. During peg formation and post harvest season it was 4.13 and 3.11 respectively. In *summer* season it were 4.24±1.67 with highest during harvesting season (5.96) when the rodent activity was

Burrows of *Bandicota bengalensis* in groundnut field

Plate 2. Burrow opening in centre of field

Plate 3. Excavated burrow at the centre of the field

Plate 4. Burrow opening on the bund

Plate 5. Excavated burrow on the bund

maximum and minimum during germination stage (2.63) when the rodent activity was minimum. During peg formation and post harvest season it was 4.13 and 3.11 respectively (Table 7).

4.4.2.3 Tunnels

The study revealed that the burrow usually branched off into several lanes or tunnels distributed in different directions. The branching was not uniform. The tunnel passageways were almost circular and were widened at the junctions where branching was seen. The mean diameter of the tunnels in different cropping seasons was 7.07±0.77 cm. During *Kharif* season it was 7.15±1.01cm with highest during harvesting season (8.13 cm) when rodent activity was maximum in field and lowest during germination stage (6.11 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 7.21cm and 6.97 cm, respectively. In *summer* season it were 7.1±1.00 cm with highest during harvesting season (7.99 cm) when the rodent activity was maximum and minimum during germination stage (6.01 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 7.30 cm and 6.81 cm, respectively (Table 7).

4.4.2.4 Blind tunnels

The lesser bandicoot rats often hoarded food grains in a few of the blind alleys or tunnels situated in the burrow. Most of the burrows excavated revealed the presence of a deeper blind tunnel which was frequently associated with the nest area. Such blind tunnels always had a greater depth compared to rest of the blind tunnels in a burrow. The maximum and minimum vertical depth of a blind tunnel was 58 cm and 18 cm respectively. When bandicoot burrows were excavated the adult rats were found always in these blind alleys or blind tunnels, trying to hide their presence by covering themselves with the dugout loose soil. Sometimes, the adult rats were found to seal the tunnel completely with

Table 7. Burrow characteristics of *Bandicota bengalensis* in and around groundnut

Season	Crop stage	Month	Total length of burrow (cm)	Depth (cm)	Diameter of tunnel (cm)	No. of openings	Diameter of opening (cm)	No. of blind tunnels	Length of blind tunnels (cm)	No. of side tunnels	No. of food chambers
Kharif	Germination	July	293.30	33.10	6.11	2.03	6.13	2.13	38.10	2.13	0.93
	Peg formation	Sep	397.10	42.30	7.31	4.03	6.35	3.57	52.43	3.61	1.16
	Harvesting	Nov	621.00	72.10	8.13	5.01	6.98	3.65	54.89	4.01	1.96
Mean±SD			**437.13±167.48**	**52.6±27.58**	**7.15±1.01**	**3.69±1.52**	**6.49±0.44**	**3.11±0.85**	**48.77±8.74**	**3.25±0.99**	**1.35±0.54**
Post-harvest (Off season)	December		314.12	36.79	6.97	3.11	6.27	3.51	51.40	3.00	1.89
Summer	Germination	Jan	335.70	28.10	6.01	2.63	5.96	2.34	45.76	2.03	1.04
	Peg formation	Feb	481.30	38.36	7.19	4.13	6.18	3.71	63.36	3.62	1.36
	Harvesting	Apr	633.10	62.42	7.99	5.96	6.43	4.08	65.41	5.13	2.03
Mean±SD			**483.37±148.71**	**42.96±17.61**	**7.1±1.00**	**4.24±1.67**	**6.19±0.24**	**3.37±0.91**	**58.17±10.8**	**3.59±1.55**	**1.47±0.50**
Post-harvest (Off season)		May	423.78	33.63	6.81	3.16	6.09	3.66	62.11	3.33	2.18
Total Mean±SD			**437.43±132.04**	**43.35±15.54**	**7.07±0.77**	**3.76±1.29**	**6.29±0.31**	**3.33±0.69**	**54.18±9.36**	**3.36±1.01**	**1.50±0.49**
t- value			**2.11***	**2.03***	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

N=40

*Significance at P= 0.05: NS-Non significant

earthen packing. The mean lengths of the blind tunnels in cropping season were 54.18±9.36 cm. During *Kharif* season it was 48.77±8.74 cm with highest during harvesting season (54.89 cm) when the rodent activity was maximum and lowest during germination stage (38.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 52.43 cm and 51.40 cm, respectively. In *summer* season it were 58.17±10.8 cm with highest during harvesting season (65.41 cm) when the rodent activity was maximum and minimum during germination stage (38.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 63.36 cm and 62.11 cm, respectively (Table 7).

4.4.2.5 Depth of the burrows

Mean depth of the burrow and its variation in stages of the crop and seasons were 43.35±15.54 cm. During *Kharif* season it was 52.6 ±27.58 cm with highest during harvesting season (72.10 cm) when the rodent activity was maximum and lowest during germination stage (33.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 42.30 cm and 36.79 cm respectively. In *summer* season it were 42.96±17.61 cm with highest during harvesting season (62.42 cm) when the rodent activity was maximum and minimum during germination stage (28.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 51.10 cm and 37.66 cm respectively (Table 7).

4.4.2.6 Length of the burrow

Mean total length of the burrow were 437.43±132.02 cm. During *Kharif* season it was 437.13±167.48 cm with highest during harvesting season (621 cm) when the rodent activity was maximum and lowest during germination stage (293.30 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 397.10

cm and 314.12 cm respectively. In *summer* season it was 483.37±148.41 cm with highest during harvesting season (633.10 cm) when the rodent activity was maximum and minimum during germination stage (335.70 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 481.30 cm and 423.78 cm, respectively (Table 7).

4.4.2.7 Nest/brood chamber

Both male and female rat burrows were having identical nest chambers. Male rats utilized the chambers for resting purposes and the female rats in addition to resting use the chambers for brood rearing purpose also. The shape of the nest/brood chamber in general varied from spherical to oblong. It showed a shallow depression of 3 to 6 cm in the floor of the chamber. Nesting materials were used as mat for lining the floor of the nest chambers. The mat of nesting materials lining the floor of the chamber was 2 to 4 cm in thickness. Materials used for nesting are stem and root cuttings of ginger grass (*Panicum repens* L), ragi straw and dried leaves of jack fruit tree (*Artocarpus integrifolia* L). The nest size varied from 8cm x6 cm to 20 cm x 15 cm.

4.4.2.8 Food chambers

Food chambers were encountered in the burrows of both the sexes. The food chamber was oblong to semi-circular in shape, with smooth inner walls. Usually the food chambers were built in middle of the tunnel passageways and occasionally noticed at the end of the blind tunnels. Size of the food chamber varied from 4cm x 6 cm to 35 cm x 45 cm. Rat faeces were observed in the food chambers than in any parts of the burrow. The mean number of food chambers was 1.50±0.49. During *Kharif* it was 1.35±0.54 with highest during harvesting season (1.96 cm) and lowest during germination stage (0.93 cm). During peg formation and post harvest season it was 1.16 cm and 1.89 cm respectively.

During *summer* season it was 1.47±0.50 with highest during harvesting season (2.03 cm) and lowest during germination stage (1.04 cm). During peg formation and post harvest season it was 1.36 cm and 2.18 cm, respectively (Table 7).

4.4.2.9 Hoarding habits

Both the male and female rats stored large quantities of food grain in the burrows. The ear heads of crops brought by rats were not only found stored in the food chamber but were even noticed in the blind tunnel ends, at junctions were the tunnel branched and sometimes in the middle of tunnel passages. The mean quantity of hoarded material were 21.63±37.47 g and 25.4±43.99 g, respectively in *Kharif* and *summer* season with a total mean of 36.24±39.06 g**.** Groundnut hoarding (Plate 6) was noticed only during harvesting season and post harvest season with 64.90 g average per burrow during *Kharif* season and 67.43 g in preceding post harvest season. During *summer* season it was 76.20 g and 81.35 g in the preceding post harvest season. Noticeably more hoarding of groundnut pods were seen in post harvest season because of non availability of food material during off seasons. Ragi ear heads collected from the burrow were cut at the base, leaving a short stock of 1 cm to 3cm. During *summer* season, in addition to other hoarding materials neatly cut ginger grass were found in blind tunnels and sometimes found in nest chambers also. The rhizomes were being nibbled by adult rats and remnants of nibbled pieces of rhizomes were found scattered at different points of the burrow (Table 8).

4.4.2.10 Breeding season and litter size

Young ones of the rats were found during peg formation and harvesting seasons of *Kharif* and *summer* crops. When the burrows were dug the unfurled young blind rattling’s noticed within brood chamber (Plate 7). The mean numbers of litter size was noticed 2.72±0.84 with

Plate 6. Hoarded groundnut pods inside food chamber

Plate 7. Litters inside the nest chamber

Table 8. Hoarding behaviour and litter size of *Bandicota bengalensis* in and around groundnut field

Season	Crop stage	Month	No. of food chambers	Quantity of material hoarded (g)	Materials hoarded	No. of litters/burrow
Kharif	Germination	July	0.93	_		0.00
	Peg formation	Sep	1.16	-	Ragi earheads	3.77
	Harvesting	Nov	1.96	64.90	Groundnut pods	2.87
Mean±SD			**1.35±0.54**	**21.63±37.47**	**-**	**3.32±0.64**
Post-harvest (Off season)	December		1.89	67.43	Groundnut pods	1.96
Summer	Germination	Jan	1.04	_	_	0.00
	Peg formation	Feb	1.36	_	*Cyanodon dactylon, Panicum repens*	2.23
	Harvesting	April	2.03	76.20	Groundnut pods	3.63
Mean±SD			**1.47±0.50**	**25.4±43.99**	**-**	**2.93±0.99**
Post-harvest (Off season)		May	2.18	81.35	Groundnut pods	1.83
Total Mean±SD			**1.50±0.49**	**36.24±39.06**	**-**	**2.72±0.84**

3.32±0.64 and 2.93±0.99 in *Kharif* and *summer*, respectively. Litter size was observed more during peg formation stage of *Kharif* (3.77) and this lead to increase of population in harvesting season but in *summer* season during peg formation period (2.23) it was less compared to harvesting stage (3.63) mainly due to adverse climatic conditions. During post harvest season after *Kharif* and *summer* it litter size were 1.96 and 1.83, respectively (Table 8).

4.5 Indian Gerbil, *Tatera indica* (Hardwicke)

4.5.1 Burrowing behavior

Soil mounds were also noticed near the openings of the burrow. The disposed loose soil by rats was frequently noticed in the form of scattered heaps usually near the main opening and occasionally in front of all the openings in a burrow. The burrow openings were exposed without being covered by the excavated soil. Appearances of fresh soil mounds near openings of burrows were noticed immediately after the rain.

4.5.2 Burrow structure

4.5.2.1 Main entrance

Main entrance of the burrow was difficult to locate but the presence of large scattered heap of soil in front of an opening which always had a larger diameter was considered to be main entrance (Plate 8 and Plate 10). The mean diameters of the main entrance of burrows were 6.10±0.74 cm. During *Kharif* season it was 6.78±0.24 cm with highest during harvesting season (7.03 cm) when the rodent activity was maximum and lowest during germination stage (6.55 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 6.76 cm and 6.64 cm respectively. In *summer* season it were 5.50±0.46 cm with highest during harvesting season (5.98 cm) when the rodent activity was maximum and minimum during germination stage (5.07 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 5.47 cm and 5.33 cm, respectively (Table 9).

4.5.2.2 Number of openings

The burrow openings were exposed circular in shape and live burrows were kept clean which did not had any cobwebs or grass blades criss-crossing the mouth of the opening (Plate 8, Plate 9, Plate 10 and Plate 11). All these openings were sealed from inside with earthen plugs at a distance ranging from 10 to 150 cm below the soil surface. The thickness of the earthen seal varied from 5 to 45 cm and usually packing was hard during summer. The data regarding the mean number of the openings recorded were 2.59±0.54 cm. During *Kharif* season it was 2.68±0.66 cm with highest during harvesting season (3.35 cm) when the rodent activity was maximum and lowest during germination stage (2.03 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 2.65 cm and 2.24 cm respectively. In *summer* season it were 2.74±0.65 cm with highest during harvesting season (3.41 cm) when the rodent activity was maximum and minimum during germination stage (2.11 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 2.69 cm and 2.31 cm, respectively (Table 9).

4.5.2.3 Tunnels

In the burrows main entrance always first leads to a broadened chamber termed as nest/brood chamber from where usually further branched of tunnels were formed. The tunnel passageways were circular and widened at the junctions where branching was seen. The mean diameter of the tunnel passage ways in different cropping seasons were 3.61±0.30 cm. During *Kharif* season it was 3.62±0.41cm with highest

Table 9. Burrow characteristics of *Tatera indica* in and around groundnut field

Season	Crop stage	Month	Total length of burrow (cm)	Depth (cm)	Diameter of tunnel (cm)	No. of openings	Diameter of opening(cm)	No. of blind tunnels	Length of blind tunnels (cm)	No. of side tunnels
Kharif	Germination	July	163.13	15.30	3.21	2.03	6.55	1.68	28.23	1.53
	Peg formation	Sep	226.41	25.42	3.63	2.65	6.76	1.71	30.79	2.03
	Harvesting	Nov	333.23	33.10	4.03	3.35	7.03	1.79	31.50	2.88
Mean±SD			**240.92±85.97**	**24.60±8.93**	**3.62±0.41**	**2.68±0.66**	**6.78±0.24**	**1.75±0.06**	**31.45±0.50**	**2.15±0.68**
Post-harvest (Off season)		Dec	188.19	17.73	3.55	2.24	6.64	1.70	30.01	1.90
Summer	Germination	Jan	183.22	13.13	3.25	2.11	5.07	1.73	30.09	1.57
	Peg formation	Feb	252.15	18.93	3.71	2.69	5.47	1.84	32.97	2.31
	Harvesting	April	363.23	27.3	3.99	3.41	5.98	1.88	33.33	2.95
Mean±SD			**266.2±90.82**	**19.79±7.12**	**3.65±0.37**	**2.74±0.65**	**5.50±0.46**	**1.86±0.03**	**33.15±0.25**	**2.28±0.69**
Post-harvest (Off season)		May	226.47	15.98	3.53	2.31	5.33	1.81	32.13	1.86
Total Mean±SD			**242.00±71.89**	**20.86±6.97**	**3.61±0.30**	**2.59±0.54**	**6.10±0.74**	**1.79±0.07**	**31.79±1.27**	**2.13±0.54**
t test			**2.01***	**2.22***	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

N=40

*Significance at P= 0.05: NS-Non significant

Burrows of *Tatera indica* in groundnut field

Plate 8. Burrow opening on the bund

Plate 9. Excavated burrow on the bund

Plate 10. Burrow opening away from the bund

Plate 11. Excavated burrow away from the bund

during harvesting season (4.03 cm) when rodent activity was maximum in field and lowest during germination stage (3.21 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 3.63 cm and 3.55 cm respectively. In *summer* season it were 3.65±0.37 cm with highest during harvesting season (3.99 cm) when the rodent activity was maximum and minimum during germination stage (3.25 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 3.71 cm and 3.53 cm, respectively (Table 9).

4.5.2.4 Blind tunnel

The mean lengths of the blind tunnel in the burrows in different seasons of Indian gerbil were 3.61±0.30 cm. During *Kharif* season it was 3.62±0.41cm with highest during harvesting season (4.03 cm) when rodent activity was maximum in field and lowest during germination stage (3.21 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 3.63 cm and 3.55 cm respectively. In *summer* season it were 3.65±0.37 cm with highest during harvesting season (3.99 cm) when the rodent activity was maximum and minimum during germination stage (3.25 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 3.71 cm and 3.53 cm respectively (Table 9).

4.5.2.5 Depth of the burrow

Mean depth of the burrow and its variation in stages of the crop and seasons were 20.86±6.97 cm. During *Kharif* season it was 24.60 cm ± 8.93 cm with highest during harvesting season (33.10 cm) when the rodent activity was maximum and lowest during germination stage (15.30 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 25.42 cm and 17.73 cm respectively. In *summer* season it was 19.97±7.12 cm with highest during harvesting season (27.3 cm) when the rodent activity was maximum and minimum during germination stage (13.13 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 18.93 cm and 15.98 cm respectively (Table 9).

4.5.2.6 Length of the burrow

Mean total length of the burrow were 242 ± 71.89 cm. During *Kharif* season it was 240.92±85.97 cm with highest during harvesting season (333.23 cm) when the rodent activity was maximum and lowest during germination stage (163.13 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 226.46 cm and 188.19 cm respectively. In *summer* season it was 266.2±90.82 cm with highest during harvesting season (363.23cm) when the rodent activity was maximum and minimum during germination stage (183.22 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 252.15 cm and 226.47 cm, respectively (Table 9).

4.5.2.7 Nest/brood chamber

The shape of the nest/brood chamber in general varied from spherical to oblong. It showed a shallow depression of 3 to 6 cm in the floor of the chamber. Nesting materials were used as mat for lining the floor of the nest chambers. The mat of nesting materials lining the floor of the chamber was 2 to 4 cm in thickness. Materials used for nesting are *Cyanodon dactylon*, ragi straw and dried stems of *Leucas aspera*. The burrows usually had only one nesting chambers. The size of the nest chambers in burrows varied from 10 cm x 16 cm to 35 cm x 30 cm.

4.5.2.8 Food chambers

The mean number of food chambers was 1.04±0.35. During *Kharif* it was 0.91±0.40 with highest during harvesting season (1.32 cm) and lowest during germination stage (0.52 cm). During peg formation and post harvest season it was 0.91 cm and 1.01 cm respectively. During *summer* season it was 1.02±0.34 with highest during harvesting season (1.37 cm) and lowest during germination stage (0.68 cm). During peg formation and post harvest season it was 1.01 cm and 1.56 cm, respectively.

4.5.2.9 Hoarding habits

Indian gerbils stored good quantities of food in the food chamber especially during summer season. The mean quantity of hoarded material were 32.07±55.54 and 36.83±63.80, respectively in *Kharif* and *summer* season with a total mean of 52.09±56.47. The hoarded materials in different seasons and in different stages of the crop and the groundnut hoarding (Plate 12) was noticed only during harvesting season and post harvest season with 96.20 g average per burrow during *Kharif* season and 79.01 g in preceding post harvest season. During *summer* season it was 110.50 g and 121.00 g in the preceding post harvest season. Noticeably more hoarding of groundnut pods were seen in post harvest season because of non availability of food material during off seasons (Table 10).

4.5.2.10 Breeding season and litter size

Young ones of the rats were found during peg formation and harvesting seasons of *Kharif* and *summer* crops (Plate 13). The mean numbers of litter size was 4.96±1.70 with 5.36±1.77 and 5.47±2.14 in *Kharif* and *summer*, respectively. Litter size was observed more during peg formation stage of *Kharif* (7.38) and this lead to increase of

Plate 12. Hoarded groundnut pods inside the burrow

Plate 13. Young ones

Table 10. Hoarding behaviour and litter size of *Tatera indica* in and around groundnut field

Season	Crop stage	Month	No. of food chambers	Quantity of material (g)	Materials hoarded	No. of litters/burrow
Kharif	Germination	July	0.52	0.00	_	0.00
	Peg formation	September	0.91	45.2	Ragi earheads, *Cyanodon dactylon*	7.38
	Harvesting	November	1.32	96.20	Groundnut pods, Ragi earheads,	4.07
Mean±SD			**0.91±0.40**	**32.07±55.54**	**-**	**5.36±1.77**
Post-harvest (Off season)		December	1.01	79.01	Groundnut pods	3.58
Summer	Germination	January	0.68	0.00	_	0.00
	Peg formation	February	1.01	56.2	Ragi earheads, *Cyanodon dactylon*	7.89
	Harvesting	April	1.37	110.50	Groundnut pods, Ragi earheads,	3.83
Mean±SD			**1.02±0.34**	**36.83±63.80**	**-**	**5.47± 2.14**
Post-harvest (Off season)		May	1.56	121.00	Groundnut pods	3.63
Total Mean±SD			**1.04±0.35**	**52.09±56.47**	**-**	**4.96±1.70**

population in harvesting season and in *summer* season during peg formation period (7.89) it was also more compared to harvesting (3.83). During germination stage none of burrows excavated have litter but in off seasons litters was noticed but numbers were less that is 3.58 and 3.63, respectively (Table 10).

4.6 Common Indian field mouse, *Mus booduga* (Gray)

4.6.1 Burrowing behavior

Unlike other rodents the burrows of *Mus booduga* was simple and shallow. The burrows could be distinguished from those of other rodent species by smaller opening of about one cm with scooped soil before the burrow opening.

4.6.2 Burrow structure

4.6.2.1 Main entrance

The presence of mice in burrows could be ascertained by the degree of freshness or wetness of pellets at the entrance. The entrance and particularly the exit of the burrows were camouflaged making them fairly inconspicuous (Plate 14 and Plate 15). The mean diameters of the main entrance of burrows were 6.10±0.74 cm. During *Kharif* season it was 2.32±0.29 cm with highest during harvesting season (2.70 cm) when the rodent activity was maximum and lowest during germination stage (2.01 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 2.28 cm and 2.11 cm respectively. In *summer* season it were 2.42±0.37 cm with highest during harvesting season (2.84 cm) when the rodent activity was maximum and minimum during germination stage (2.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 2.33 cm and 2.22 cm, respectively (Table 11).

4.6.2.2 Number of openings

The mean numbers of burrow openings were 1.50±0.53 numbers. During *Kharif* season it was 1.33±0.58 with highest during harvesting season (2.00) when the rodent activity was maximum and lowest during germination stage (1.00) when the rodent activity was minimum. During peg formation and post harvest season it was 1.00 and 2.00 respectively. In *summer* season it was 1.33±0.58 with highest during harvesting season (2.00) when the rodent activity was maximum and minimum during germination stage (1.00) when the rodent activity was minimum. During peg formation and post harvest season it was 1.00 and 2.00, respectively (Table 11).

4.6.2.3 Tunnels

The inlet tunnel was running downward from the entrance in case of *M. booduga* burrows. The mean diameter of the tunnel passageways in different cropping seasons were 2.33±0.18 cm. During *Kharif* season it was 2.32±0.24 cm with highest during harvesting season (2.57 cm) when rodent activity was maximum in field and lowest during germination stage (2.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 2.30 cm and 2.19 cm respectively. In *summer* season it were 2.40±0.19 cm with highest during harvesting season (2.62 cm) when the rodent activity was maximum and minimum during germination stage (2.23 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 2.36 cm and 2.28 cm respectively (Table 11).

4.6.2.4 Depth of the burrow

Mean depth of the burrow and its variation in stages of the crop and seasons were 8.74±4.19 cm. During *Kharif* season it was 10±5.35 cm

Burrows of *Mus booduga* in groundnut field

Plate 14. Burrow opening

Plate 15. Excavated burrow

with highest during harvesting season (16.10 cm) when the rodent activity was maximum and lowest during germination stage (6.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 7.80 cm and 6.97 cm respectively. In *summer* season it were 8.9±5.07 cm with highest during harvesting season (14.70 cm) when the rodent activity was maximum and minimum during germination stage (5.30 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 6.70 cm and 6.21 cm respectively (Table 11).

4.6.2.5 Length of the burrow

Mean total length of the burrow were 80.41±14.69 cm. During *Kharif* season it was 79.83±17.66 cm with highest during harvesting season (98.30 cm) when the rodent activity was maximum and lowest during germination stage (63.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 78.10 cm and 71.24 cm respectively. In *summer* season it was 86.03±18.31 cm with highest during harvesting season (105.60cm) when the rodent activity was maximum and minimum during germination stage (63.10 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 83.20 cm and 74.47 cm, respectively (Table 11).

4.6.2.6 Blind tunnels

Mean number of blind tunnels were 0.44±0.76 with mean length of 7.08±12.26 cm in *Kharif* and 0.47±0.82 with mean length of 8.75±15.14 cm in *summer* season. During *Kharif* season mean length during harvesting season was 21.25 and during post harvest season it was 18.23 cm. In *summer* season mean length of blind tunnel were 26.24 cm and 21.23 cm during harvesting season and post harvest season, respectively (Table 13)

Table 11. Burrow characteristics of *Mus booduga* in and around groundnut field

Season	Crop stage	Month	Total length of burrow (cm)	Depth (cm)	Diameter of tunnel (cm)	No. of openings	Diameter of opening(cm)	No. of blind tunnels	Length of blind tunnels (cm)	No. of side tunnels	No. of food chambers
Kharif	Germination	July	63.10	6.10	2.10	1.00	2.01	0.00	0.00	0.00	0.00
	Peg formation	Sept	78.10	7.80	2.30	1.00	2.28	0.00	0.00	0.00	0.00
	Harvesting	Nov	98.30	16.10	2.57	2.00	2.70	1.32	21.25	2.13	0.00
Mean±SD			**79.83±17.66**	**10±5.35**	**2.32±0.24**	**1.33±0.58**	**2.33±0.35**	**0.44±0.76**	**7.08±12.26**	**0.67±1.15**	**0.00**
Post-harvest (Off season)		Dec	71.24	6.97	2.19	2.00	2.11	1.04	18.23	2.00	0.00
Summer	Germination	Jan	69.30	5.30	2.23	1.00	2.10	0.00	0.00	0.00	0.00
	Peg formation	Feb	83.20	6.70	2.36	1.00	2.33	0.00	0.00	0.00	0.00
	Harvesting	April	105.60	14.70	2.62	2.00	2.84	1.43	26.24	2.28	0.00
Mean±SD			**86.03±18.31**	**8.9±5.07**	**2.40±0.19**	**1.33±0.58**	**2.42±0.37**	**0.47±0.82**	**8.74±15.14**	**0.76±1.31**	**0.00**
Post-harvest (Off season)		May	74.47	6.21	2.28	2.00	2.22	1.13	21.23	2.00	0.00
Total Mean±SD			**80.41±14.69**	**8.74±4.19**	**2.33±0.18**	**1.50±0.53**	**2.32±0.29**	**0.62±.66**	**10.86±11.8**	**1.05±1.12**	**0.00**
t test			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	_

N=40

*Significance at P= 0.05: NS-Non significant

Table 12.Hoarding behaviour and litter size of *Mus booduga* in and around groundnut field

Season	Crop stage	Month	No. of food chambers	Materials hoarded	No. of litters/ burrow
Kharif	Germination	July	0.00	0.00	0.00
	Peg formation	September	0.00	0.00	3.89
	Harvesting	November	0.00	0.00	2.92
Mean±SD			**0.00**	**0.00**	**2.82±0.97**
Post-harvest (Off season)		December	0.00	0.00	1.43
Summer	Germination	January	0.00	0.00	0.00
	Peg formation	February	0.00	0.00	3.23
	Harvesting	April	0.00	0.00	2.83
Mean±SD			**0.00**	0.00	**2.02±1.7**
Post-harvest (Off season)		May	0.00	0.00	1.38
Total Mean±SD			**0.00**	**0.00**	**2.24±1.34**

4.6.2.7 Nest/brood chamber

The inlet tunnel of each species ended in a chamber resembling the nest chamber, but without bedding. The nest/brood chamber in general was globular in shape. Nests padded with dried grass and straw.

4.6.2.8 Hoarding habits

The burrows of *Mus booduga* did not contain any hoarded material except a few leaves and straw of the neighbouring crops (Table 12).

4.6.2.9 Breeding season and litter size

Young ones of the rats were found during germination, peg formation and harvesting seasons of *Kharif* crops and in off season after *Kharif*. The mean numbers of litter size was 2.24±1.34 with 2.82±0.97 and 2.02±1.7 in *Kharif* and *summer*, respectively. Litter size was observed more during peg formation stage of *Kharif* (3.89) and this lead to increase of population in harvesting season and in *summer* season during peg formation period (3.23) it was also more compared to harvesting (2.83). During germination stage none of burrows excavated have litter but in off seasons litters was noticed but numbers were less that is 1.43 and 1.38, respectively (Table 12).

4.7 Brown spiny mouse, *Mus platythrix* (Gray)

4.7.1 Burrowing behavior

Burrows of *Mus platythrix* were simple and shallow.

4.7.2 Burrow structure

4.7.2.1 Main entrance

Rodents exhibited a peculiar behaviour of pebble collection around the surface openings (Plate 16 and Plate 17). The mean diameters of the main entrance of burrows were 3.25±0.08 cm. During *Kharif* season it was 3.21±0.08 cm with highest during harvesting season (3.28 cm) when the rodent activity was maximum and lowest during germination stage (3.12 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 3.23cm and 3.17 cm respectively. In *summer* season it was 3.30±0.09 cm with highest during harvesting season (3.39 cm) when the rodent activity was maximum and minimum during germination stage (3.22 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 3.30 cm and 3.25 cm respectively (Table 13).

4.7.2.2 Number of openings

The mean numbers of burrow openings were 1.84±0.56 numbers. During *Kharif* season it was 1.69±0.60 with highest during harvesting season (2.10) when the rodent activity was maximum and lowest during germination stage (1.36) when the rodent activity was minimum. During peg formation and post harvest season it was 1.96 and 1.42 respectively. In *summer* season it was 2.21±0.50 with highest during harvesting season (2.78) when the rodent activity was maximum and minimum during germination stage (1.84) when the rodent activity was minimum. During peg formation and post harvest season it was 2.02 and 1.62 respectively (Table 13).

4.7.2.3 Tunnels

The mean diameter of the tunnel passageways in different cropping seasons were 2.53±0.20 cm. During *Kharif* season it was 2.55±0.25 cm with highest during harvesting season (2.81 cm) when rodent activity was maximum in field and lowest during germination stage (2.31 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 2.52 cm and 2.44 cm respectively. In *summer* season it were 2.59±0.25 cm with highest during harvesting season (2.83

Burrow of *Mus platythrix* in groundnut field

Plate 16. Burrow opening

Plate 17. Excavated burrow

Table 13. Burrow characteristics of *Mus platythrix* in and around groundnut field

Season	Crop stage	Month	Total length of burrow (cm)	Depth (cm)	Diameter of tunnel (cm)	No. of openings	Diameter of opening(cm)	No. of blind tunnels	Length of blind tunnels (cm)	No. of pebbles
Kharif	Germination	July	161.38	17.80	2.31	1.36	3.12	1.33	26.67	14
	Peg formation	Sep	212.64	22.30	2.52	1.96	3.23	1.89	33.13	18
	Harvesting	Nov	262.34	26.40	2.81	2.10	3.28	2.04	38.76	21
Mean±SD			**212.12±50.48**	**22.17±4.30**	**2.55±0.25**	**1.69±0.60**	**3.21±0.08**	**1.75±0.37**	**32.85±6.04**	**17.67±3.51**
Post-harvest (Off season)		Dec	191.91	20.08	2.44	1.42	3.17	1.92	35.09	15
Summer	Germination	Jan	170.23	15.60	2.33	1.84	3.22	1.56	28.56	12
	Peg formation	Feb	223.12	18.01	2.61	2.02	3.30	2.01	36.09	17
	Harvesting	April	283.33	24.30	2.83	2.78	3.39	2.21	41.23	23
Mean±SD			**222.56±56.58**	**19.30±4.49**	**2.59±0.25**	**2.21±0.50**	**3.30±0.09**	**1.92±0.33**	**35.29±6.37**	**17.33±5.51**
Post-harvest (Off season)		May	203.44	16.97	2.42	1.91	3.25	2.06	38.96	16
Total Mean±SD			**213.55±42.28**	**20.18±3.81**	**2.53±0.20**	**1.94±0.56**	**3.25±0.08**	**1.85±0.30**	**35.72±4.99**	**17±3.62**
t test			**2.11***	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

N=40

*Significance at P= 0.05: NS-Non significant

cm) when the rodent activity was maximum and minimum during germination stage (2.33 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 2.61 cm and 2.42 cm respectively (Table 13).

4.7.2.4 Depth of the burrow

Mean depth of the burrow and its variation in stages of the crop and seasons were 20.18±3.81 cm. During *Kharif* season it was 22.17± 4.30 cm with highest during harvesting season (26.40 cm) when the rodent activity was maximum and lowest during germination stage (17.80 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 22.30 cm and 20.08 cm respectively. In *summer* season it were 19.30±4.49 cm with highest during harvesting season (24.30 cm) when the rodent activity was maximum and minimum during germination stage (15.60 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 18.01 cm and 16.97 cm respectively (Table 13).

4.7.2.5 Length of the burrow

Mean total length of the burrow was 213.55 42.88 cm. During *Kharif* season it was 212.12±50.48 cm with highest during harvesting season (262.34 cm) when the rodent activity was maximum and lowest during germination stage (161.38 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 212.64 cm and 191.91 cm respectively. In *summer* season it was 222.56±56.58 cm with highest during harvesting season (283.33 cm) when the rodent activity was maximum and minimum during germination stage (170.23 cm) when the rodent activity was minimum. During peg formation and post harvest season it was 223.12 cm and 203.44 cm respectively (Table 13).

4.7.2.6 Blind tunnels

Mean number of blind tunnels were 1.75±0.37 with mean length of 32.85±6.04 cm in *Kharif* and 1.92±0.33 with mean length of 35.29±6.37 cm in *summer* season in *M. platythrix.* During *Kharif* season mean length was highest during harvesting season (38.76 cm) and lowest during germination stage (26.67 cm). During peg formation and post harvest season it was 33.13 cm and 35.09 cm respectively. In *summer* season mean length of blind tunnel was highest during harvesting season (41.23 cm) and minimum during germination stage (28.56 cm). During peg formation and post harvest season it was 36.09 cm and 38.96 cm, respectively (Table 13).

4.7.2.7 Pebbles

The mean number of pebbles found in burrows were 17.67±3.51 and 17.33±5.51 during *Kharif* and *summer*, respectively. During *Kharif* season number of pebbles was highest during harvesting season (21) and lowest during germination stage (14). During peg formation and post harvest season it was 18 and 15, respectively. In *summer* season number of pebbles was highest during harvesting season (23) and minimum during germination stage (12). During peg formation and post harvest season it was 17 and 16, respectively.

4.7.2.8 Nest/brood chamber

The inlet tunnel of each species ended in the nest chamber padded with leaves, dried grass and straw.

4.7.2.9 Hoarding habits

The burrows of *Mus platythrix* did not contain any hoarded materials (Table 14).

Table 14. Hoarding behaviour and litter size of *Mus platythrix* in and around groundnut field

Season	Crop stage	Month	Quantity of material	Materials hoarded	No. of side tunnels	No. of litters/burrow
Kharif	Germination	July	0.00	0.00	1.86	1.59
	Peg formation	Sept	0.00	0.00	2.03	3.59
	Harvesting	Nov	0.00	0.00	2.86	1.96
Mean±SD			**0.00**	**0.00**	**2.25±0.533**	**2.59±0.87**
Post-harvest (Off season)	December		0.00	0.00	2.09	1.99
Summer	Germination	Jan	0.00	0.00	1.98	1.62
	Peg formation	Feb	0.00	0.00	2.11	3.69
	Harvesting	April	0.00	0.00	2.98	2.11
Mean±SD			**0.00**	**0.00**	**2.35±0.54**	**2.71±0.85**
Post-harvest (Off season)		May	0.00	0.00	2.15	2.03
Total Mean±SD			**0.00**	**0.00**	**2.23±0.43**	**2.50±0.71**

4.7.2.10 Breeding season and litter size

The young ones of the rats were found during germination, peg formation and harvesting seasons of both *Kharif* and *summer* crops and also in off seasons. Mean litter size was observed more during *summer* season (2.71±0.85) and during *Kharif* it was 2.59±0.87 with a total mean of 2.50±0.71. Litter size was observed more during peg formation stage of *Kharif* (3.59) and it was 1.59 and 1.96 during germination and harvesting stages, respectively. In *summer* season during peg formation period (3.69) it was also more compared to harvesting (2.11) and it was 1.62 during germination stage, but in off seasons number of litters were less that is 1.99 and 2.03, respectively (Table 14).

4.8 Larger bandicoot rat – *Bandicota indica* (Bechstein)

4.8.1 Burrowing behavior

Burrow systems of *Bandicota indica* were elaborated. Burrow can be recognized by the fresh, wet globules of earth and soft faecal matter at the burrow opening.

4.8.2 Burrow structure

4.8.2.1 Main entrance

The mean diameters of the main entrance of burrows were 8.95±0.27 cm. During *Kharif* season in harvesting stage it was 8.76 cm and in *summer* harvesting stage it was 9.14 cm (Table 15).

4.8.2.2 Number of openings

Each burrow system consisted of two to four openings on the surface. The data regarding the mean number of the openings was 3.21 in *Kharif* harvesting stage and in *summer* harvesting stage was 3.5 (Table 15).

4.8.2.3 Tunnels

From each opening, an oblique tunnel passed into the ground, giving branches at regular intervals. Some branches were interconnecting, others ended blindly. The mean diameters of tunnels were 12.75±0.35 cm. In *Kharif* harvesting stage it was 13 cm and in *summer* harvesting stage it was 12.5 cm (Table 15).

4.8.2.4 Depth of the burrow

The maximum depth of the burrow recorded was 112.5 cm. Mean depth of the burrow in *Kharif* harvesting stage it was 113 cm and in *summer* harvesting stage it was 93.2 cm (Table 15).

4.8.2.5 Length of the burrow

The maximum total length of the burrow is ranged from 124 to 556 cm. Mean length of the burrow in *Kharif* harvesting stage it was 503 cm and in *summer* harvesting stage it was 525 cm. Total mean length was 514.00±15.56 cm (Table 15).

4.8.2.6 Blind tunnels

The mean numbers of blind tunnels were 3.5 cm and 72.8 cm, respectively during *Kharif* and *summer* season and mean length of blind tunnels were 4.2 cm and 78.3 cm, respectively (Table 15).

4.8.2.7 Side tunnels

In *Bandicota indica* the mean number of side tunnels were 3.19 and 3.55 in *Kharif* and *summer* season, respectively

4.8.2.8 Nest/brood chamber

The brood chamber was made in centrally located dilated part of the burrow system. It was padded with a variety of materials such as paper, cloth, grass, leaf etc.

Table 15. Burrow characteristics of *Bandicota indica* in and around groundnut field

Season	Crop stage	Month	Total length of burrow (cm)	Depth (cm)	Diameter of tunnel (cm)	No. of openings	Diameter of opening (cm)	No. of blind tunnels	Length of blind tunnels (cm)	No. of side tunnels
Kharif	Germination	July	-	-	-	-	-	-	-	-
	Peg formation	Sept	-	-	-	-	-	-	-	-
	Harvesting	Nov	503	113	13	3.21	8.76	3.5	72.8	3.19
Mean			**503**	**113**	**13**	**3.21**	8.76	**3.5**	**72.8**	**3.19**
Post-harvest (Off season)		Dec	-	-	-	-	-	-	-	-
Summer	Germination	Jan	-	-	-	-	-	-	-	-
	Peg formation	Feb	-	-	-	-	-	-	-	-
	Harvesting	April	525	93.2	12.5	3.5	9.14	4.2	78.3	3.55
Mean			**525**	**93.2**	**12.5**	**3.5**	9.14	**4.2**	**78.3**	**3.55**
Post-harvest (Off season)		May	-	-	-	-	-	-	-	-
Total Mean±SD			**514.00±15.56**	**103.10±14.00**	**12.75±0.35**	**3.36±0.21**	**8.95±0.27**	**3.85±0.49**	**75.5±3.8**	**3.37±0.25**

4.8.2.9 Hoarding habits

The burrows of *Bandicota indica* did not contain any hoarded materials.

4.9 Result of effect of burrow length on its depth across different species

Regression analysis of effect on length of burrow over depth show significant difference in all the rodent species. In *B.bengalensis* per unit increase in length of the burrow there will be 0.104 unit variation in depth. It was 0.080 in *T. indica*, 0.256 in *M. booduga* and 0.74 in *M. platythrix* (Table 16).

4.10 Fauna and Flora

The soil samples extracted from the burrows of the rodents were used to study the flora or fauna content if any, with the help of staff of the Department of Pathology and Entomology. The dominant flora found was *Aspergillus spp., Pencillium spp., Rhizopus spp.* and *Mucor spp.* whereas dominant species found in fauna are *Pherethima elongata, Xenopsylla cheopis, Camponotus spp.* etc. The findings are tabulated in Table 17.

4.11 Rodent damage in Groundnut field

In present investigation it is observed that rodent damage in groundnut growing areas occurs from the sowing stage to harvesting of crop both in *Kharif* as well as *summer* seasons. Study revealed that the percentage damage by rodents in groundnut during *Kharif* season is highest during harvesting stage (8.23±0.01) and in *summer* also during harvesting stages percentage damage was highest (9.33±0.06). Minimum damage was during germination stages with 4.23±0.23 and 5.25±1.2 in

Table 16. Regression result of effect of burrow length on its depth across different species

Species	Co efficient	t value
Bandicota bengalensis	0.104	4.935**
Tatera indica	0.080	2.235*
Mus booduga	0.256	4.978**
Mus platythrix	0.074	3.509**

Note: * Indicates significant at 5 % level, ** indicates significant at 1 % level

Table 17. Flora and Fauna associated with rodents burrows in groundnut fields

Season	*Bandicota bengalensis*		*Tatera indica*		*Mus platythrix*		*Mus booduga*		*Bandicota indica*	
	Flora	**Fauna**	**Flora**	**Fauna**	**Flora**	**Fauna**	**Flora**	**Fauna**	**Flora**	**Fauna**
Kharif	**Aspergillus spp. Pencillium spp., Mucor spp.*	**Pherethima elongata*	**Rhizopus spp.*	**Camponotus spp, Xenopsylla cheopis*	**Mucor spp.*	**Camponotus spp, *Pherethima elongata ,*	**Pencillium spp, Mucor spp.*	**Camponotus spp.*	**Aspergillus spp. Pencillium spp, Rhizopus spp.*	**Camponotus spp., * Pherethima elongata*
Post – harvest (Off season)	**Aspergillus spp. Pencillium spp.Rhizopus spp.,*	**Pherethima elongate, Xenopsylla cheopis.*	**Pencillium spp., Rhizopus spp., Mucor spp.*	**Camponotus spp, Xenopsylla cheopis*	**Aspergillus spp. Pencillium spp., Mucor spp.*	**Camponotus spp., *Pherethima elongata Xenopsylla cheopis*	**Rhizopus spp., Mucor spp.*	**Camponotus spp.*	**Aspergillus spp. Mucor spp.*	*Pherethima elongata,,Xenopsylla cheopis*
Summer	**Aspergillus spp. *Pencillium spp., Rhizopus spp., Mucor spp.*	**Camponotusspp, Pherethima elongata*	**Rhizopus spp., Mucor spp.*	**Camponotus spp, Pherethima elongata*	**Aspergillus spp. Pencillium spp., Mucor spp.*	**Camponotus spp., Pherethima elongata*	**Aspergillus spp.*	**Camponotus spp. *Pherethima elongata ,Xenopsylla cheopis*	**Aspergillus spp., Pencillium spp., Rhizopus spp.*	**Pherethima elongata*
Post – harvest (Off season)	**Aspergillus spp. Rhizopus spp., Mucor spp.*	*Camponotus spp, Pherethima elongata ,*	**Aspergillus spp. Mucor spp.*	**Pherethima elongata*	**Aspergillus spp. Pencillium spp., Mucor spp.*	**Camponotus spp., Pherethima elongata*	**Aspergillus spp. Mucor spp.*	**Pherethima elongata*	**Aspergillus spp. Rhizopus spp.*	**Pherethima elongata , Xenopsylla cheopis*

***Dominant species found**

Kharif and *summer*, respectively (Table 18, Plate 18, Plate 19, Plate 20 and Plate 21).

4.12 Evaluation of rodenticides and snap traps in groundnut field during *Kharif* season

A significant reduction of live burrow counts was recorded due to treatments. Among the treatments best was T_{11} (2% Zn_3P_2 baiting at germination stage and Al_2 $(PO_3)_2$ application in peg formation stage) which recorded 82 per cent reduction in live burrows which is on par with T_9 (54 Snap traps per ha at germination stage and 2% Zn_3P_2 baiting at peg formation stage) with 80 per cent reduction (Plate 22, Plate 23 and Plate 24) followed by T_8 (Al_2 $(PO_3)_2$ application in burrows at peg formation stage), T_{10} (Bromadiolone (0.25%) CB at germination stage and 2% Zn_3P_2 baiting at peg formation stage) and T_{12} (2% Zn_3P_2 baiting at germination stage and Bromadiolone (0.25%) CB at peg formation stage) all with 78 per cent reduction of live burrow counts during *Kharif* compared to control. Per cent reduction of rodent population for different treatments during *Kharif* season is given in Table 19.

The highest yield of 1381kg/ha was also recorded in T_{11} followed by T_9 (54 Snap traps per ha at germination stage and 2% Zn_3P_2 baiting at peg formation stage) with 1363.65 kg/ha, T_{12} (2% Zn_3P_2 baiting at germination stage + Bromadiolone (0.25%) CB at peg formation stage) with 1335.19 kg/ha, T_{10} (Bromadiolone (0.25%) CB at germination stage and 2% Zn_3P_2 baiting at peg formation stage) with 1321.71 kg/ha and T_8 (Al_2 $(PO_3)_2$ application in burrows at peg formation stage) with 1306.11 kg/ha (Table 21)

4.13 Evaluation of rodenticides and snap traps in groundnut field during *summer* season

Significant reductions of live burrow counts were recorded due to treatments during *summer* season. The best treatment was T_{11} (2% Zn_3P_2

Table18. Rodent damage at crop growth stages of groundnut

Season	Crop stage	Rodent damage (%) Mean ± SD	Dominant species causing damage	Nature of damage
Kharif	Germination	4.23±1.23	*Bandicota bengalensis, Tatera indica*	Seed damage
	Peg formation	6.92±1.19	*Bandicota bengalensis, Tatera indica, Mus booduga*	Plant damage
	Harvesting	8.23±2.35	*Bandicota bengalensis, Tatera indica, Mus booduga, Mus platythrix*	Pod damage and Hoarding matured pods
Post-harvest (Off season)		1.83±1.2	*Bandicota bengalensis, Tatera indica*	Hoarding matured pods
Summer	Germination	5.25±1.2	*Bandicota bengalensis, Tatera indica, Mus booduga*	Seed damage
	Peg formation	7.21±1.89	*Bandicota bengalensis, Tatera indica, Mus booduga*	Plant damage
	Harvesting	9.33±2.26	*Bandicota bengalensis, Tatera indica, Mus booduga, Mus platythrix*	Pod damage and Hoarding
Post-harvest (Off season)		2.19±1.47	*Bandicota bengalensis, Tatera indica*	Hoarding matured pods

Damages caused by rodents in groundnut

Plate 18. At germination stage

Plate 19. At seedling stage

Plate 20. At pod formation stage

Plate 21 . By hoarding

Rodents Trapped in snap trap

Plate 22. ***Bandicota bengalensis***

Plate 23. ***Tatera indica***

Plate 24. ***Mus platythrix***

Table 19. Evaluation of rodenticides in groundnut field during *Kharif* season

Treatments	GERMINATION STAGE			PEG FORMATION STAGE			HARVESTING STAGE	REDUCTION IN POPULATION %
	Live Burrow Count/ha			Live Burrow Count//ha			Live Burrow Count//ha	
	A day before treatment	7 days after treatment	14 days after treatment	A day before treatment	7 days after treatment	14 days after treatment		
T_1	26.67±1.89	8.33±2.89	10.00±2.00	23.33±3.64	28.33±2.89	33.33±3.77	56.67±3.64	31
T_2	26.67±2.89	6.67±2.89	8.33±2.78	18.33±3.64	20.00±2.00	28.33±2.64	53.33±3.64	35
T_3	27.33±1.89	8.33±2.89	11.67±2.23	25.00±2.00	28.33±2.89	33.33±2.64	58.33±5.58	29
T_4	27.00±2.00	5.00±2.00	6.67±2.89	13.33±2.89	15.00±2.00	20.00±2.00	43.33±5.77	47
T_5	26.67±2.89	38.33±2.89	43.33±2.89	53.33±2.89	8.33±2.89	10.00±2.00	28.33±2.64	65
T_6	27.00±2.00	33.33±1.77	38.33±3.29	53.33±2.89	11.67±2.89	18.33±7.64	33.33±2.89	59
T_7	27.33±1.89	38.33±2.89	43.33±2.89	53.00±1.89	8.33±2.89	13.33±2.89	25.00±2.00	69
T_8	26.67±1.89	33.33±2.89	38.33±3.24	53.33±2.89	5.00±0.00	6.67±2.89	18.33±2.64	78
T_9	26.67±2.89	8.33±1.77	10.00±2.00	23.33±2.64	6.67±2.89	8.33±2.89	16.67±2.89	80
T_{10}	27.00±2.00	8.33±1.67	13.33±2.89	28.33±2.64	6.67±2.89	8.33±2.89	18.33±2.89	78
T_{11}	26.67±2.89	6.67±2.89	10.00±2.00	20.00±2.00	5.00±0.00	6.67±2.89	15.00±2.00	82
T_{12}	27.33±2.89	6.67±1.27	10.00±2.00	25.00±2.00	8.33±2.89[c]	11.67±2.89	18.33±2.89	78
T_{13}	27.33±2.89	38.33±1.58	43.33±2.89	53.33±2.89	58.33±2.89	61.67±3.77	81.67±5.77	0
SEM	0.98	0.43	0.58	0.54	1.3	0.93	2.19	
F test	NS	*	*	*	*	*	*	
CD	2.91	1.39	1.56	2.13	3.54	1.69	4.10	

Note: Significance at P= 0.05 level: NS-Non significant

Table 20. Evaluation of rodenticides in groundnut field during *summer* season

Treatments	GERMINATION STAGE			PEG FORMATION STAGE			HARVESTING STAGE	REDUCTION IN POPULATION %
	Live Burrow Count/ha			Live Burrow Count//ha			Live Burrow Count//ha	
	A day before treatment	7 days after treatment	14 days after treatment	A day before treatment	7 days after treatment	14 days after treatment		
T_1	31.67±2.89	13.33±2.89	15.00±2.00	26.67±2.89	33.33±3.64	38.33±2.77	63.33±3.64	24
T_2	31.67±2.89	11.67±2.89	13.33±2.89	23.33±2.89	25.00±2.66	33.33±3.64	58.33±3.64	30
T_3	30.33±2.89	13.33±2.89	16.67±2.89	30.00±2.00	33.33±3.64	38.33±3.64	63.33±3.58	24
T_4	30.00±2.00	10.00±0.00	11.67±2.89	16.67±2.89	20.00±2.00	25.00±2.00	48.33±2.77	42
T_5	31.67±2.89	43.33±2.89	48.33±2.89	58.33±2.89	13.33±2.89	16.67±2.64	33.33±2.64	60
T_6	30.00±2.00	38.33±2.77	43.33±3.64	58.33±2.89	16.67±2.89	23.33±2.64	38.33±2.89	54
T_7	30.33±2.89	43.33±2.89	48.33±2.89	55.00±0.00	13.33±2.89	18.33±2.89	30.00±3.00	63
T_8	30.67±2.89	38.33±2.89	43.33±3.64	58.33±2.89	10.00±0.00	11.67±2.89	23.33±3.64	72
T_9	31.67±2.89	13.33±2.89	15.00±2.00	28.33±3.64	11.67±2.89	13.33±2.89	21.67±2.89	74
T_{10}	30.00±2.00	13.33±2.89	18.33±2.89	33.33±3.64	11.67±2.89	13.33±2.89	23.33±2.89	72
T_{11}	30.67±2.89	11.67±2.89	15.00±2.00	25.00±2.00	10.00±0.00	11.67±2.89	20.00±2.00	76
T_{12}	30.33±2.89	11.67±2.89	15.00±2.00	30.00±2.00	13.33±2.89	16.67±2.89	23.33±2.89	72
T_{13}	31.33±2.89	43.33±2.89	48.33±2.89	58.33±2.89	63.33±2.89	66.67±5.77	83.33±2.89	0
SEM	1.20	0.60	0.46	0.66	0.87	1.12	0.98	-
F test	NS	*	*	*	*	*	*	-
CD	3.57	1.81	1.21	1.30	2.61	2.98	2.38	-

*Note :*Significance at P= 0.05 level: NS-Non significant baiting at germination stage and $Al_2(PO_3)_2$ application in peg formation stage) which recorded 76 per cent reduction in live burrows which is on par with T_9 (54 Snap traps per ha at germination stage and 2% Zn_3P_2 baiting at peg formation stage) with 74 per cent reduction followed by T_8 ($Al_2(PO_3)_2$ application in burrows at peg formation stage), T_{10} (Bromadiolone (0.25%) CB at germination stage and 2% Zn_3P_2 baiting at peg formation stage) and T_{12} (2% Zn_3P_2 baiting at germination stage and Bromadiolone (0.25%) CB at peg formation stage) all with 72 percent reduction of live burrow counts compared to control. Percent reduction of rodent population for different treatments during *summer* season is given in Table 20 (Plate 25).

The highest yield of 1351.33kg/ha was also recorded in T_{11} (2% Zn_3P_2 baiting at germination stage and $Al_2(PO_3)_2$ application in peg formation stage) followed by T_9 (54 Snap traps per ha at germination stage and 2% Zn_3P_2 baiting at peg formation stage) with 1328.17 kg/ha, T_{12} (2% Zn_3P_2 baiting at germination stage and Bromadiolone (0.25%) CB at peg formation stage) with 1308 kg/ha, T_{10} (Bromadiolone (0.25%) CB at germination stage and 2% Zn_3P_2 baiting at peg formation stage) with 1283.21 kg/ha and T_8 ($Al_2(PO_3)_2$ application in burrows at peg formation stage) with 1264.06 kg/ha yield (Table 22).

4.14 Cost: Benefit ratio in *Kharif*

However, the C:B ratio was highest (1:38.12) in T_7 (Zn_3P_2 (2%) baiting at peg formation stage) with yield of 1281.09 kg/ha followed by T_8 ($Al_2(PO_3)_2$ application in burrows at peg formation stage) and T_6 (Bromadiolone (0.25%) CB at peg formation stage) with C:B ratio of 1:32.67 and 1:30.59 with a yield of 1306.11 and 1229.63 kg/ha, respectively. Yield of groundnut and cost benefit ratios for different treatments during *Kharif* season are depicted in Table 21.

Plate 25 . Zinc phosphide poisoned *Tatera indica* in front of burrow

Table 21. Yield of groundnut in different plots during *Kharif*

Treatments	Yield (kg/ha)	Cost: Benefit ratio
T_1	1076.36[j]	1: 4.37
T_2	1111.81[i]	1:20.60
T_3	1024.00[k]	1:10.19
T_4	1190.01[h]	1:22.82
T_5	1252.27[f]	1:9.23
T_6	1229.63[g]	1:30.59
T_7	1281.09[e]	1:38.82
T_8	1306.11[d]	1:32.67
T_9	1363.65[b]	1:10.17
T_{10}	1321.71[cd]	1:5.17
T_{11}	1381.00[a]	1:21.88
T_{12}	1335.19[c]	1:21.40
T_{13}	920.80	–
SEM	**6.04**	–
F test	*	–
CD	**17.62**	–

Note: * Significance at P= 0.05 level: NS-Non significant

Table 22. Yield of groundnut in selected plots during *summer*

Treatments	Yield (kg/ha)	Cost: Benefit ratio
T_1	998.14[j]	1:2.23
T_2	1089.00[i]	1:20.39
T_3	979.68[k]	1:7.82
T_4	1141.01[h]	1:20.45
T_5	1211.30[f]	1:8.71
T_6	1190.19[g]	1:28.61
T_7	1239.11[e]	1:36.56
T_8	1264.06 [d]	1:30.88
T_9	1328.17[b]	1:9.83
T_{10}	1283.21[cd]	1:4.10
T_{11}	1351.33[a]	1:21.44
T_{12}	1308.00[c]	1:21.09
T_{13}	900.31	_
SEM	**17.05**	_
F test	*	_
CD	**49.76**	_

Note: *Significance at P= 0.05 level: NS-Non significant

4.15 Cost: Benefit ratio in *summer*

The C:B ratio was highest (1:36.56) in T_7 (Zn_3P_2 (2%) baiting at peg formation stage) with yield of 1239.11 kg/ha followed by T_8 (Al_2 $(PO_3)_2$ application in burrows at peg formation stage) and T_6 (Bromadiolone (0.25%) CB at peg formation stage) with C:B ratio of 1:30.88 and 1:28.61 with a yield of 1264.06 and 1190.19 kg/ha, respectively. Yield of groundnut and cost benefit ratios for different treatments during *summer* season are given in Table 22.

V. DISCUSSION

Since very little information is available on burrowing behavior, burrow pattern, breeding season, litter size, hoarding habits, faunal associates of the burrows of rodents in groundnut crop in the region of Karnataka. therefore detailed studies on these aspects were undertaken during present investigations. The study was conducted during *Kharif, summer* and off season mainly to know the entire habitat ecology of the field rodents associated with the groundnut field.

5.1. Burrowing behavior

The lesser bandicoot rat burrows were clearly marked by the presence of heaps of soil at different points along the burrow length. All the openings were covered completely by the excavated loose soil which was heaped on the surface in the form of soil mounds. The soil mounds appear in the form of “Mole hills”. The amount of soil excavated by the bandicoot adults differed from burrow to burrow. The mean weight of the soil thrown out was 5.55±3.1 kg. The mole hill formation due to excavated soil mounds in lesser bandicoots burrows have been reported by Shakunthala (1976), Bhaduria and Mathur (1993) and Sood Pankaj and Chand Prem (2007). Jain (1970) reported that Indian gerbils make burrows with and without soil mounds. In the present study it was observed with soil mounds and burrows were more frequent in dry portion of the field which matches with the studies made by Srivastava (1968) who revealed that the burrows of *T. indica* were more extensive in barren fields, than in irrigated groundnut fields. Unlike other rodents burrows of *Mus booduga* and *Mus platythrix* was simple and shallow. The burrows could be distinguished from those of other rodent species by smaller opening of about one cm with scooped soil before the burrow opening. However, in case of *M. platythrix*, there was a collection of pebble growing in front of hives. These findings are in accordance with Rao (1980) who reported that, the *Mus spp.* burrows were simple.

5.2. Burrow patterns

5.2.1 Main entrance

Mean diameter of burrow of all rodent species varies with the stages of the crop and noticed maximum during harvesting stage .Sood Pankaj and Chand Prem (2007) also reported that mean diameter of the burrow openings varies with the stages of the crop and climatic condition. During excavation it was also observed that burrows were kept sealed, perhaps to prevent the entry of snakes and prevent desiccation. Similar view has been expressed by Jarvis and Sale (1971) as a precautionary measure by rodents. *Mus platythrix* exhibited a peculiar behaviour of pebble collection around the surface openings. Earlier workers also revealed the pebble collecting behavior of *M. platythrix* (Chandrahas, 1974; Malhi *et al.*, 1987; and Prakash *et al.*, 1971).

5.2.2 Burrow openings

The surface burrow openings of lesser bandicoot rat were externally covered by the excavated soil heaps. The openings were sealed on the surface with the packing of loose soil and packing was not usually hard. The mean numbers of openings observed were 3.76±1.29 and with a range of 1-4. Sood Pankaj and Chand Prem (2007) reported the mean diameter of the burrow openings was 3.1 cm and Maqbool *et al.* (2011) reported the mean number of openings of 2.3±0.28 and the range of 1-3. The differences in the mean burrow openings and range of the present study may be due to location of burrows or due to changes in type of crop and soil conditions. In the present investigation it was found that mean number burrow openings of *Tatera indica* was 2.59±0.54 and the mean diameter 6.10±0.74. The burrow of *T. indica* had 2-3 entrances with 10-13cm in diameter (Yiggit *et al.*, 2001). Differences observed in the present investigation in the mean diameter of burrow opening may be due to different type of sites and soil conditions. Study also revealed the mean numbers of openings was 1.50±0.53 and mean diameter is 2.32±0.29 for *Mus booduga.* Similar findings were made by Chandana and Garg (1982). In *Mus platythrix* mean number of openings and mean diameter of burrow opening was found to be 1.84±0.56 and 3.25±0.08, respectively. The present results are in agreement with the findings of Malhi and Parshad (1987) who reported that *M. platythrix* burrows had 1 to 3 surface openings.

5.2.3 Tunnels

During the present investigation the burrow usually branched off into several lanes or tunnels distributed in different directions. The branching was not uniform either in lesser bandicoot or in Indian gerbil. The tunnel passageways were almost circular and widened at the junctions where branching was seen. Sood Pankaj and Chand Prem (2007) and Maqbool *et al.* (2011) reported that burrow branching was too intense in lesser bandicoots compared to other rodent species. But in present study burrow branching was too intense for both lesser bandicoots and Indian gerbils. Deviation from the earlier study may be due to soil and terrain variations. The inlet tunnel was running downward from the entrance in case of *M. booduga* burrows. The mean diameter of the tunnel passageways in different cropping seasons were 2.33±0.18 cm. In *M. platythrix* mean diameter of the tunnel in different cropping seasons were 2.53±0.20 cm. However, larger bandicoots burrow have high variations. Arjunwadkar and Gadgil (1974) also reported variations in larger bandicoots burrows.

5.2.4 Depth of the burrows:

In the present investigation the maximum depth of the burrow of *Bandicota bengalensis* was 89 cm and it varies from season to season and from stages of the crop .It was found maximum (72.10 cm) during harvesting stage in *Kharif season* and low during germination stage (28.10 cm) in *summer* season. Maqbool *et al.* (2011) reported that lesser bandicoots make deeper burrows during rainy season. It corroborates with present study but with slight variation that deepest burrows were observed in harvesting season. This may be due to well establishment of rodents in groundnut fields. In Indian gerbil the maximum depth of 44cm of the burrow was recorded and it varies with seasons. Goyal and Ghosh (1993) reported similar observation that *T. indica* showed a seasonal shift in maximum burrow depth i.e. from 35cm in winter to 45-50cm in summer. The maximum depth of the burrow recorded were 18 cm and 38.6 cm for *Mus booduga* and *Mus platythrix* respectively. In *M. booduga* depth of burrow was maximum during harvesting stage (16.10 cm) in *Kharif* season and minimum during germination stage (5.30 cm) in *summer* season and in *M. platythrix* highest during harvesting stage (26.40 cm) of *Kharif* season and minimum during germination stage (15.60 cm) of *summer* season. Sunita Singh *et al.*, (2008) reported that, the *Mus spp.* burrow depth varies between 10 to 60 cm which had variation from present study due to variations in soil texture, structure and crop. The maximum depth of the burrow recorded was 112.5 cm in *Bandicota indica*. Arjunwadkar and Gadgil (1974) revealed that, the maximum depth of the larger bandicoot rat burrows ranged from 23 to 115 cm which supports the study with maximum depth 113 cm.

5.2.5 Length of the burrow

The maximum total length of the burrow recorded were 753 cm and 390 cm in *Bandicota bengalensis* and *Tatera indica,* respectively. In

Mus booduga the maximum length of the burrow was 129 cm with a range of 35 to 129 cm. Idris *et al*. (2002) observed that *Mus booduga* created long (30-90 cm) burrows with small (2.5-3.75 cm in diameter) in openings in Thar deserts. Reported differences in range in the present study may be due to changes in location or crop or soil conditions. During the study it was observed that the total length of *Mus platythrix* burrow was ranged from 75cm to 145cm. Arjun Wadkar and Madhav Gadgil (1974) reported that the total length of *Bandicota indica* burrows excavated ranged from 44 to 520 cm. In the present study the total length of the larger bandicoot rat burrows was ranged from 124 to 556 cm.

5.2.6 Nest/brood chamber

In *Bandicota bengalensis* the shape of the nest/brood chamber in general varied from spherical to oblong. It showed a shallow depression of 3 to 6 cm in the floor of the chamber. Maqbool *et al*. (2011) also reported that the nest chamber had spherical to oblong shape which supports the present investigation. Indian gerbils nest chamber shape also varies from spherical to oblong. The inlet tunnel of *Mus booduga* ended in a chamber resembling the nest chamber, but without bedding. The nest/brood chamber in general was globular in shape. Nesting chamber without bedding was reported by Sunita *et al.,* (2009) which is in accordance with the present study. The inlet tunnel of each species ended in the nest chamber padded with leaves, dried grass and straw in case of *Mus platythrix*. The brood chamber was made in centrally located dilated part of the larger bandicoot rat burrow system. It was padded with a variety of materials such as paper, cloth, grass, leaf etc. Arjunwadkar and Gadgil (1974) also reported that the burrows contained accumulations of cloth and paper pieces, particularly at the end of a blind alley or near a turning in the tunnel.

5.2.7 Hoarding habits

Chakraborty (1975) revealed that the hoarding of *B. bengalensis* was more evident in the field than in the store houses. The hoarded materials other than food grains included grass stems, leaves of paddy plants, pieces of cloth and paper. Also in a few deserted burrows a good amount of stored grains were found. A mean weight of 3.12 kg of paddy was recovered from each burrow system. *B. bengalensis* stored large quantities of food grain in the burrows. The quantity of groundnut hoarded was 36.24±39.06 g during the present investigation with 64.80 g average per burrow during *Kharif* season and 67.43 g in preceding post harvest season and it was 76.20 g and 81.35 g in the summer and preceding post harvest season respectively. Deoras (1966) recovered 6.6 kg of ground nut from 30 burrows of *B. bengalensis* while Srihari *et al.* (1979) recorded 17.1 g of groundnut pods in each *B. bengalensis* burrows. Patel and Nayak (1987) revealed that ground nut pods were hoarded to the extent 320g per burrow by the *B. bengalensis*. During present investigation in Indian gerbils groundnut hoarded was 96.20 g average per burrow during *Kharif* season and 79.01 g in preceding post harvest season. During *summer* season it was 110.50 g and 121.00 g in the preceding post harvest season. Noticeably more hoarding of groundnut pods were seen in post harvest season because of non availability of food material during off seasons. The burrows of *Mus booduga, Mus platythrix and Bandicota indica* did not contain any hoarded material except a few leaves of groundnut and straw of the neighbouring crops. Similar observations were made by Sheiker and Malhi (1983) and Urs *et al.* (1966).

5.2.8 Breeding season and litter size

Young ones of the *Bandicota bengalensis* were found both during peg formation and harvesting seasons of *Kharif* and *summer* crops. When the burrows were dug the unfurled young blind rattling's noticed within brood chamber. The maximum numbers of litter size noticed were six. According to AINP (2010), B*. bengalensis* had two seasonal peaks of breeding i.e. September–October and January- March. Moreover for *Tatera indica* the maximum number of litter size noticed was twelve. Similar observations were made by Prasad (1961) and Govinda Raj and Srihari (1987). In *Mus booduga* and *Mus platythrix* the maximum of five litters were noticed. Those results are in conformity with the findings of Bindra and Sagar (1975), Jain (1970), Chandana and Garg in (1982). However no litters were found in large bandicoot rat burrows in present investigation, as the number of burrow excavated were only two.

5.3 Density of different species of rodents in and around in Groundnut field

Bandicota bengalensis proportion in the field is more in all stages and in all seasons with highest (43.1) percentage distribution in groundnut field followed by *Tatera indica*, *Mus booduga, Mus platythrix* and *Bandicota indica.* Sood and Ubi (1975) and Hopf *et al.,* (1976) reported that *Bandicota bengalensis* was the predominant species in groundnut followed by *Millarda meltada*, *Tatera indica and Mus booduga.* In the present investigation it was observed that *Mus platythrix* was more dominant than *Millarda meltada* and later was not found in the field. This may be due to regional variation of the study and climatic factors.

5.4 Rodent incidence in Groundnut field

Mittal and Vyas (1992) observed that the population of field rodents and damage due to them increase when the unthreshed groundnut crop was kept in field for drying after its harvest. At this time rodents feed on groundnut pods or store them in the burrows for their future need. Ram Manohar (2001) reported that the activity of field rodents increases after pod formation in groundnut and was found at a

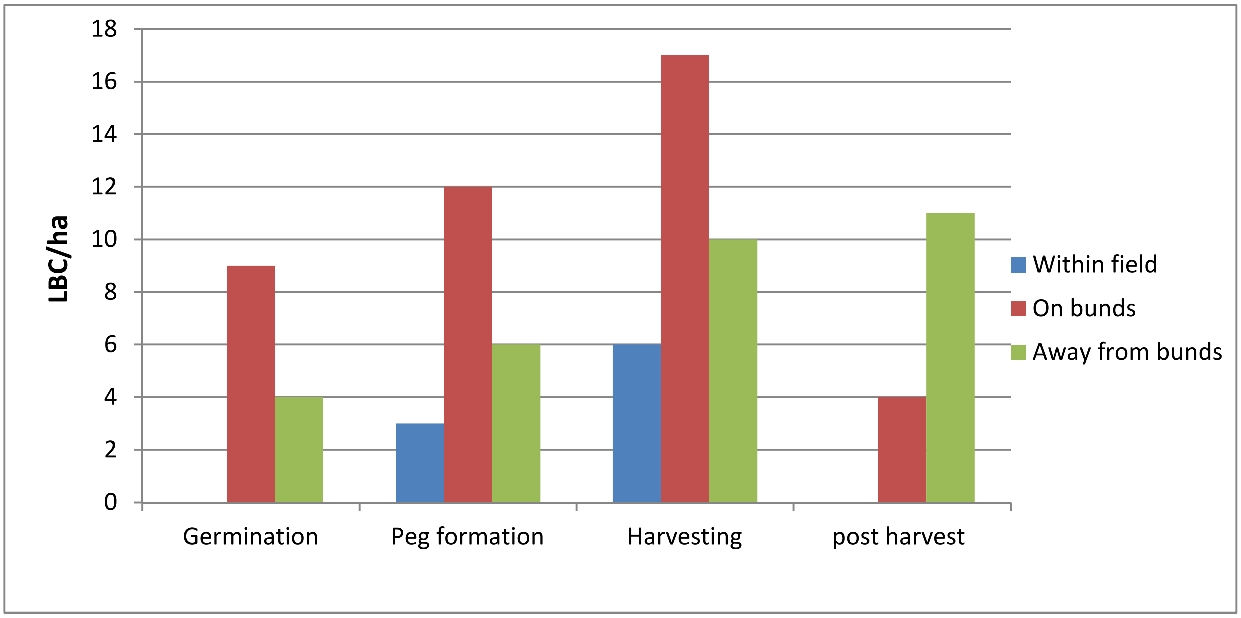

Fig 6. Population density of *Bandicota bengalensis* in and around groundnut field during *Kharif*

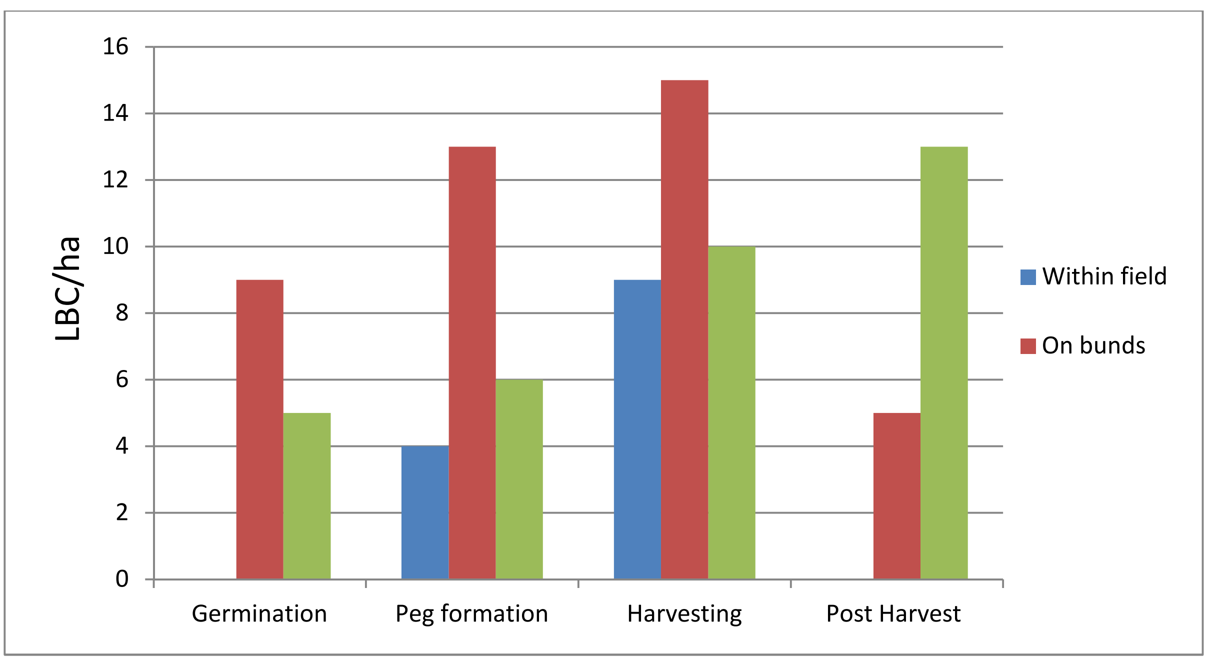

Fig 7. Population density of *Bandicota bengalensis* in and around groundnut field during *summer*

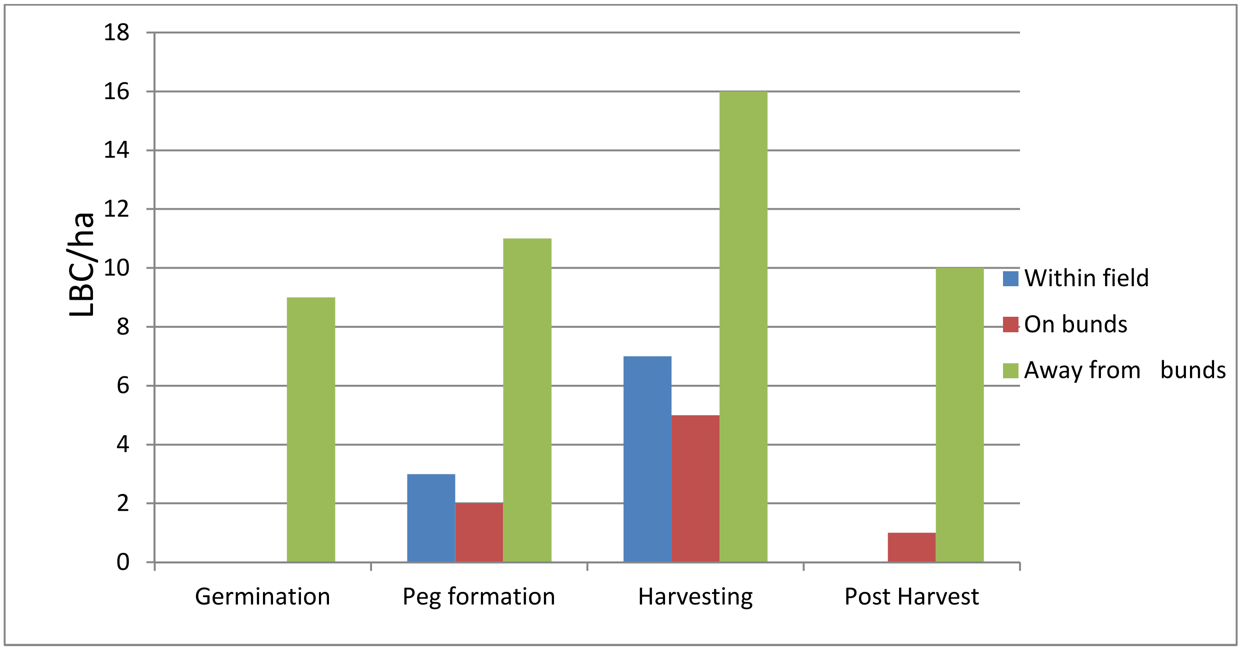

Fig 8. Population density of *Tatera indica* in and around groundnut field during *Kharif*

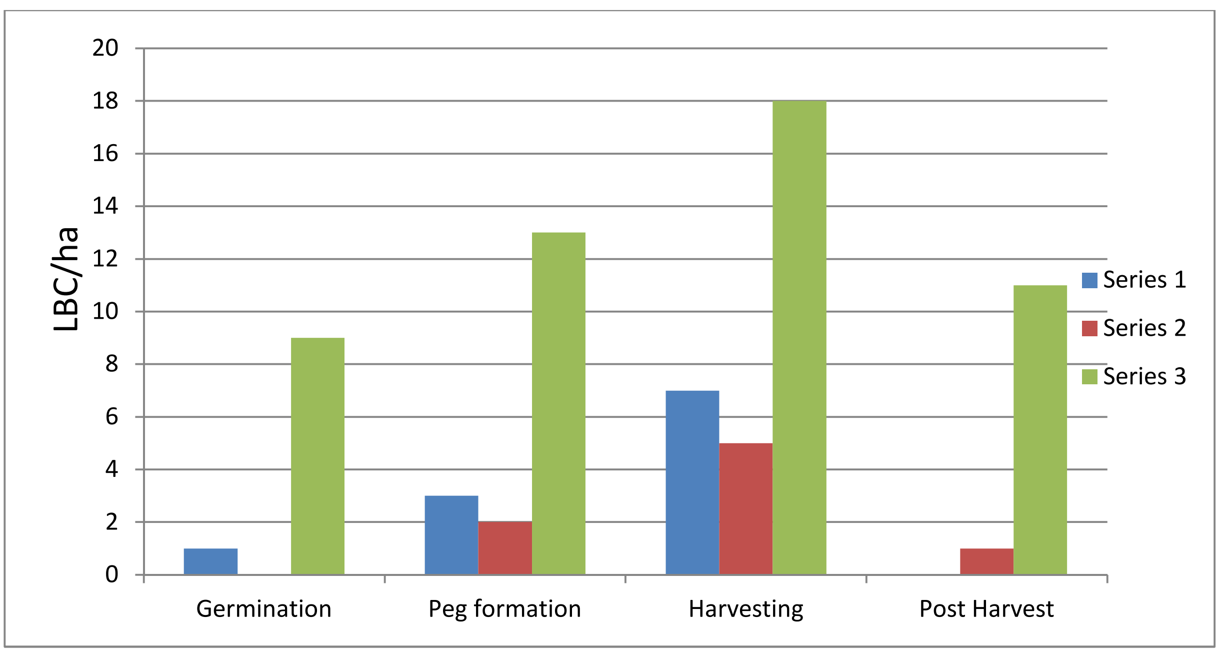

Fig 9. Population density of *Tatera indica* in and around groundnut field during *summer*

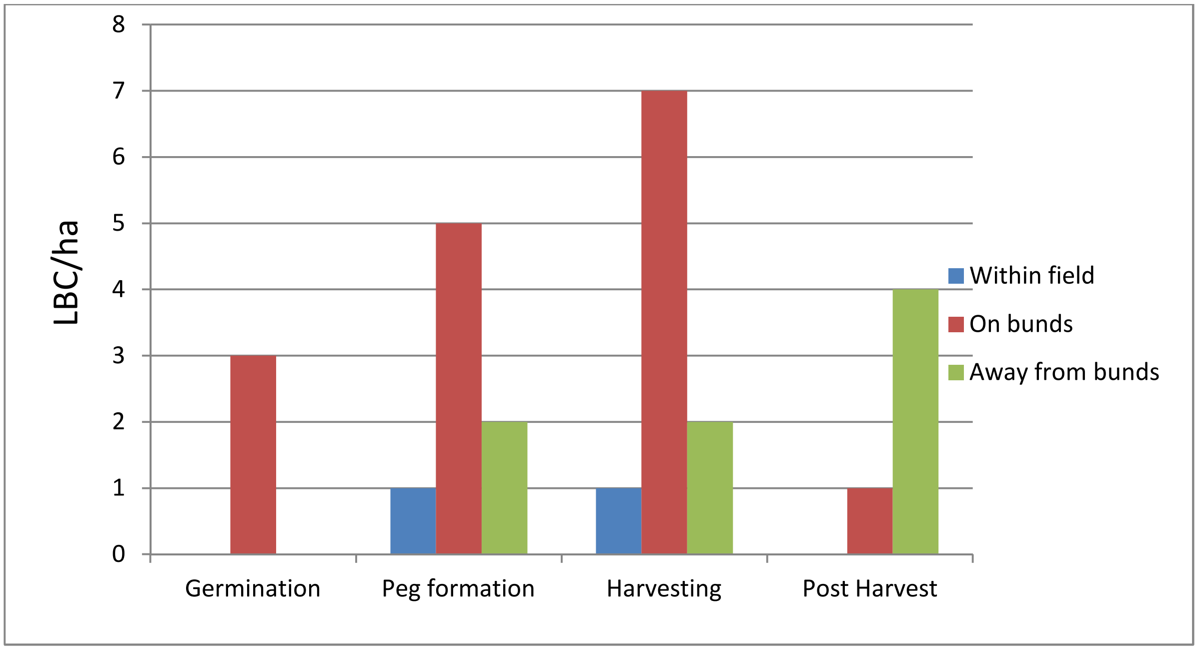

Fig 10. Population density of *Mus booduga* in and around groundnut field during *Kharif*

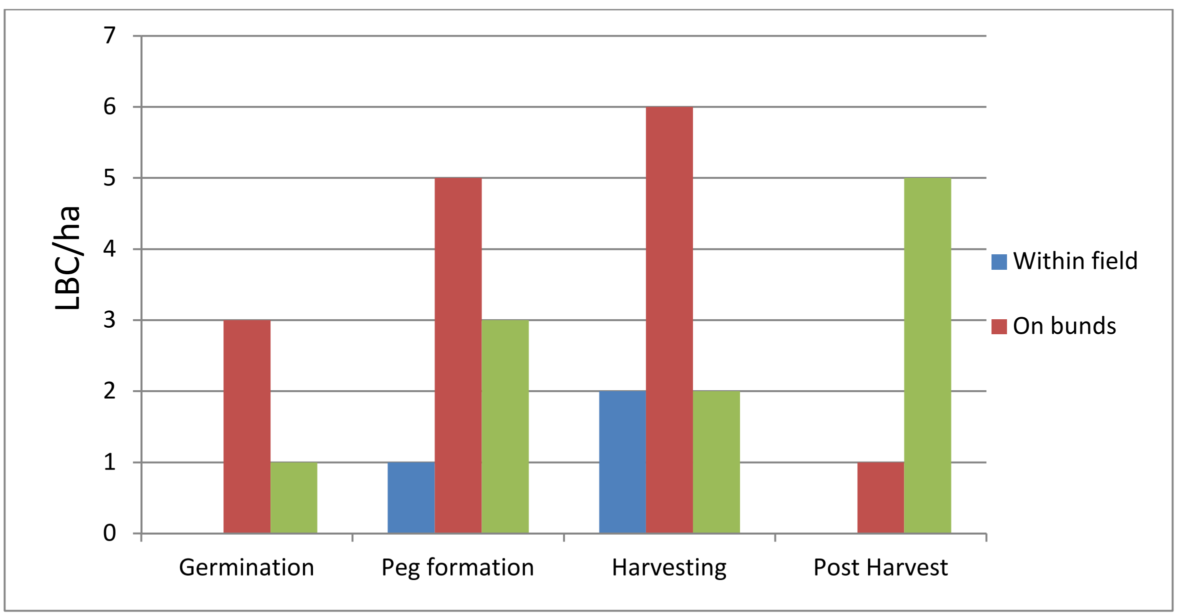

Fig 11. Population density of *Mus booduga* in and around groundnut field during *summer*

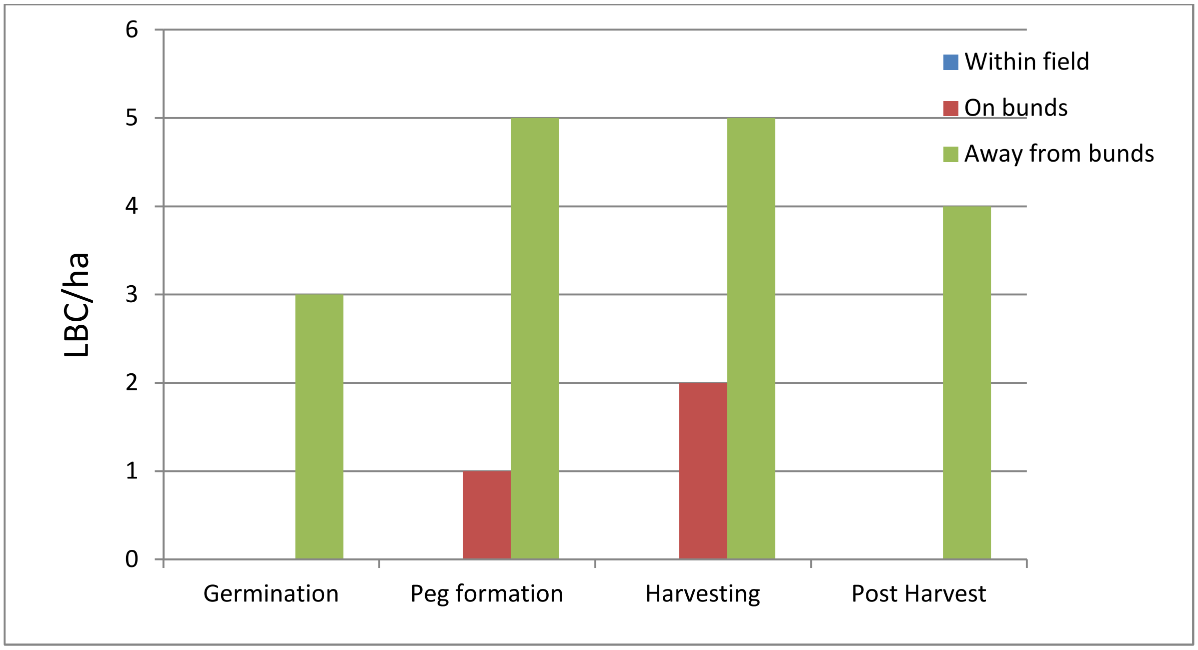

Fig 12. Population density of *Mus platythrix* in and around groundnut field during *Kharif*

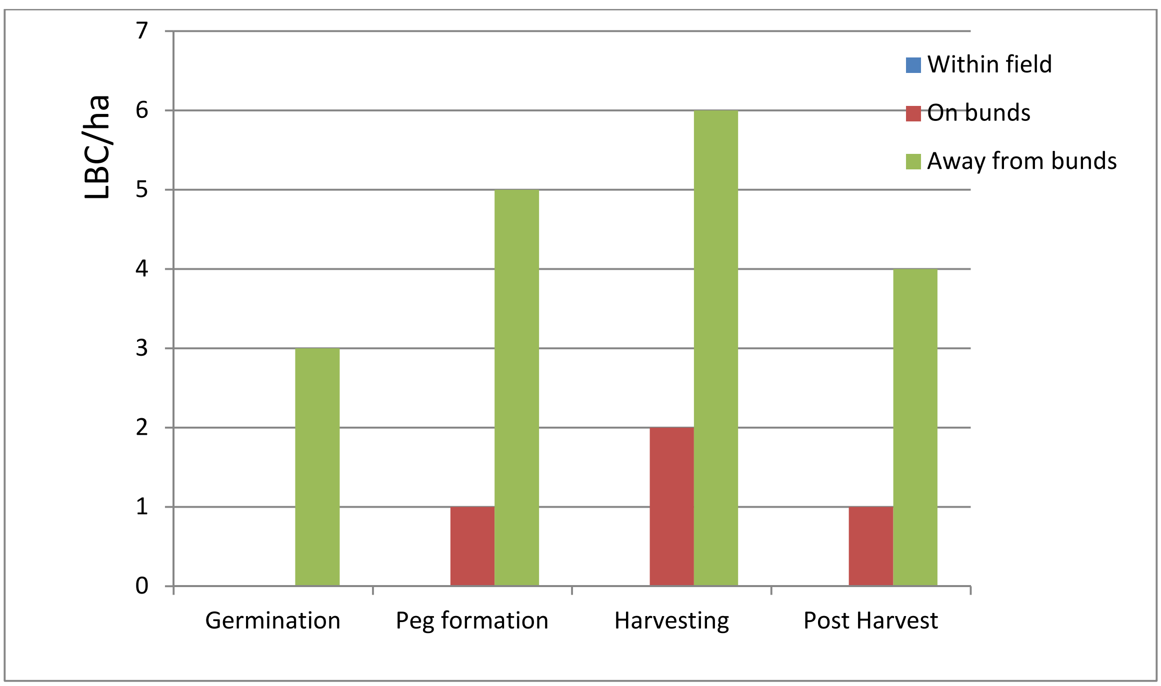

Fig 13. Population density of *Mus platythrix* in and around groundnut field during *summer*

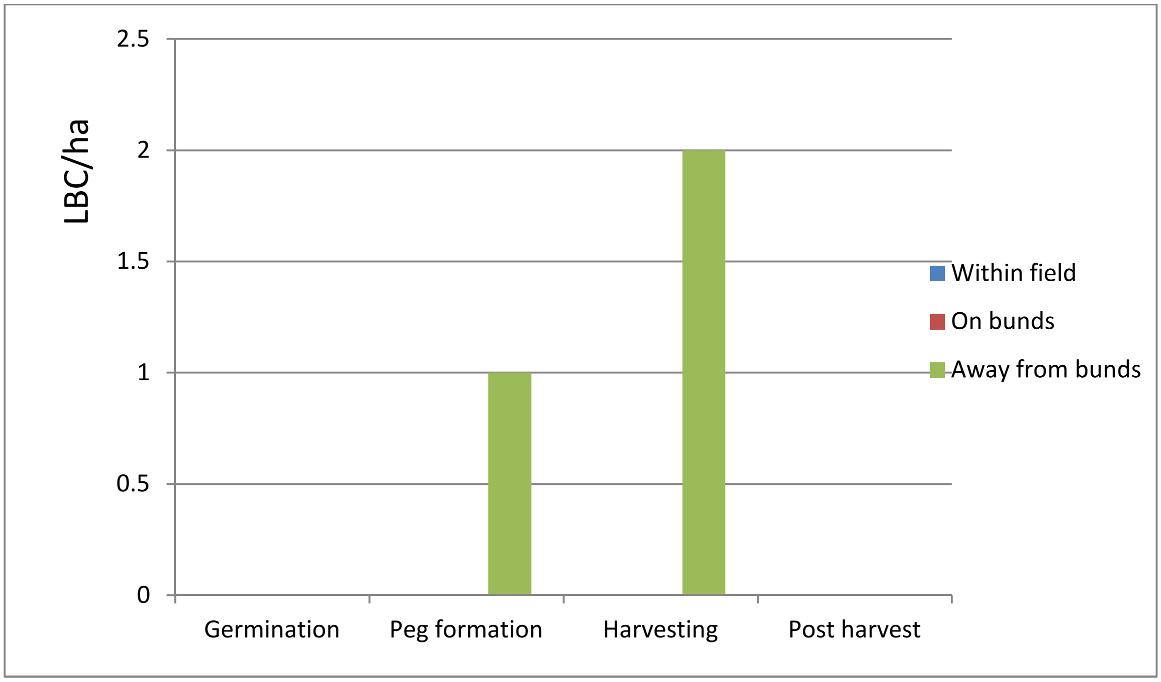

Fig 14. Population density of *Bandicota indica* in and around groundnut field during *Kharif*

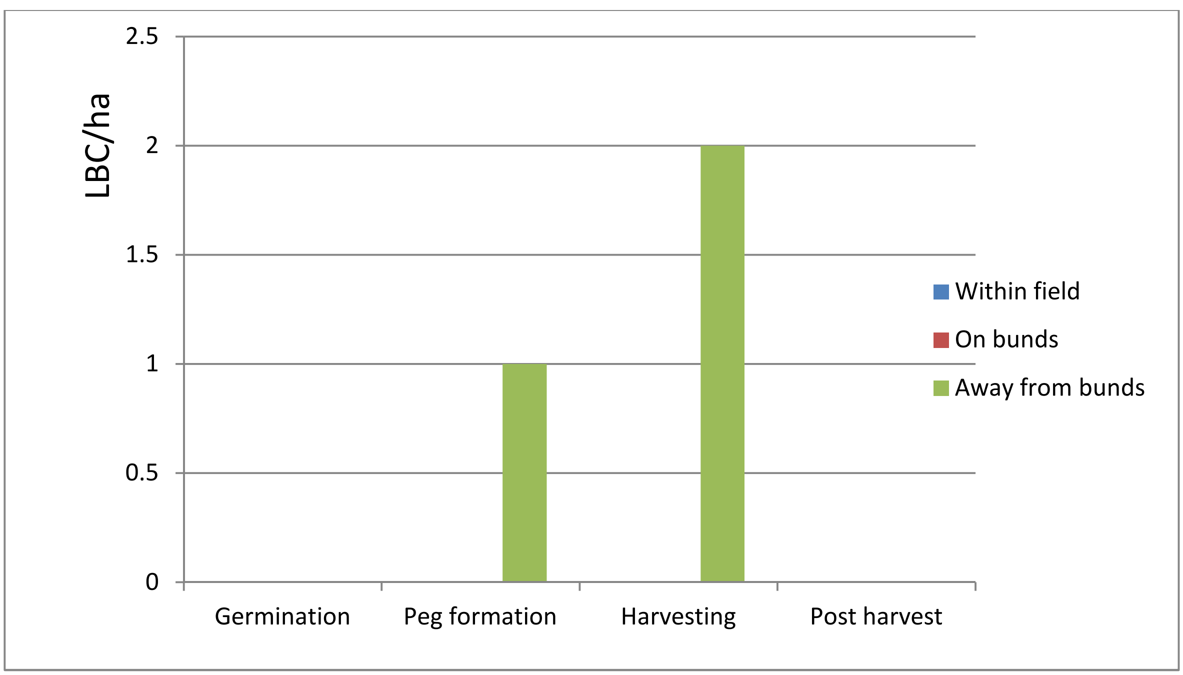

Fig 15. Population density of *Bandicota indica* in and around groundnut field during *summer*

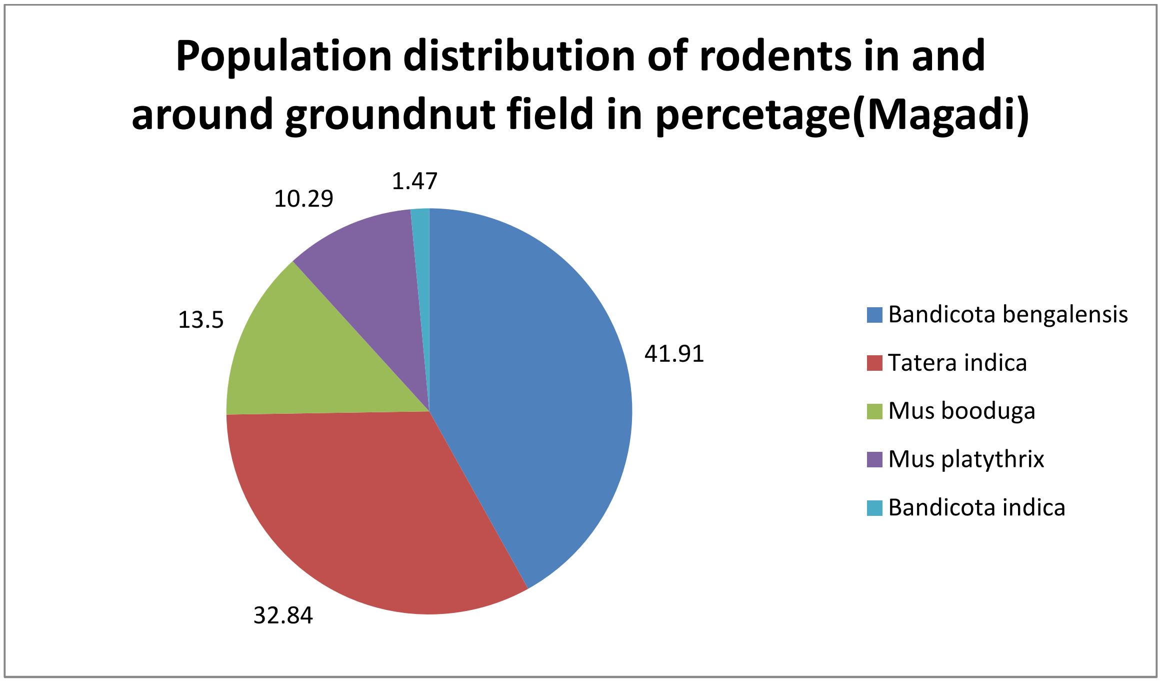

Fig 16. Percentage distribution of various rodents in and around groundnut field

maximum level at pod maturity stage of crop. In present investigation it is observed that rodent incidence on groundnut from the sowing stage and continued till harvesting of crop both in *kharif* as well as summer seasons. The present findings were in accordance with observations of earlier investigators. Mithal (1987) reached similar conclusions regarding extend of rodent damage in groundnut field. Study revealed that the percentage damage by rodents in groundnut during *Kharif* season is 19.38 with highest during harvesting stage with 8.23±0.01 and that was 21.79 in *summer* with highest loss (9.33±0.06) during harvesting stages. Minimum damage was during germination stages with 4.23±0.23 and 5.25±1.2 in *Kharif* and summer respectively. This result is in agreement with findings of Prakash and Mathur (1987) who reported that the percentage loss in groundnut due to rodents varied from 4.1 to 25.8. According to Parshad *et al.* (1987) rodents reduced peanut yield by an average of 3.86 per cent, a loss of 190.18 rupees per ha. Under sporadic conditions rodents cause a maximum of 18.97 per cent reduction in peanut yield. Even Sridhara (1992) also reported that in Karnataka 30-40 per cent seedlings of groundnut were damaged and infestation was higher at peg formation (2%) and a few percentages during harvesting stages. The dominant species being *B. bengalensis* followed by *T. indica*.

5.5 Evaluation of rodenticides and snap traps for rodent in groundnut field

In the present investigation there was a significant difference between the treatments.

Parshad (1999) revealed that the poison baiting of rodents with zinc phosphide and burrow fumigation with aluminium phosphide were common in agricultural fields. In the present investigation the best treatment was 2% Zn_3P_2 baiting at germination stage followed by Al_2 $(PO_3)_2$ applications during peg formation stage showed a per cent reduction of 82 as compared to rodent population in control in *Kharif*. Yield was 4.60 quintal more than that of the control. In *summer* same treatment showed a reduction of 76 per cent as compared to rodent population in control with a yield of 13.51 quintal per ha which was 4.51 quintal more than that of the control.

In T_9 (*Kharif* 54 Snap traps per ha at germination stage followed by 2% Zn_3P_2 baiting at peg formation stage) showed a per cent reduction of 80 as compared to rodent population in control with a yield of 13.63 quintal per ha which was 4.43 quintal more than that in control plot. Wherein during *summer* the live burrow counts during harvesting stage showed a per cent reduction of 74 as compared control with a yield of 13.28 quintal per ha which was 4.28 quintal more than that of the control.

According to Parshad (1999) a single treatment with poison bait at 80 to 90 days after planting with 2.4% Zn_3P_2 and 0.005 % bromadiolone in cereal baits at the rate of one kg per ha resulted in 58.07and 40.88 per cent rodent control, respectively in non irrigated groundnut fields. In present study Bromadiolone (0.25%) CB at germination stage followed by 2% Zn_3P_2 baiting at peg formation stage recorded per cent reduction of 78 with yield of 4.0 quintal more than that of the control during *Kharif* while recorded a per cent reduction of 72 as compared to control with a yield of 12.83 quintal per ha which was 3.83 quintal more than that of the control in *summer*. During *Kharif* 2% Zn_3P_2 baiting at germination stage followed by Bromadiolone (0.25%) CB at peg formation stage recorded a per cent reduction of 77.56 with a yield of 13.35 quintal per ha which was 4.14 quintal more than that of the control. The treatment recorded a per cent reduction of 72 in rodent population as compared to control with a yield of 13.80 quintal per ha which was 4.08 quintal more than that of the control in *summer season*. As per Butani *et al.* (2006) both the acute rodenticide, zinc phosphide (2%) and second generation anti coagulant bromadiolone (0.005%) effectively controlled rodents in groundnut fields. According to Parshad *et al.* (1987) in irrigated groundnut fields, 58 and 67 percent rodent control was achieved with zinc phosphide and bromadiolone baits. According to Mann and Bindra (1974) the baits treated with 2 per cent zinc phosphide have caused a percent reduction of 84 and 93 of field rodents in wheat fields. Romero *et al.* (1978) revealed that a control demonstration combat was carried out at one of the experimental stations with a bait prepared with a two per cent zinc phosphide in a place where it had been previously determined there was a population of 39 rats per hectare, which represents an efficiency of 53.85 per cent. As per Sridhar and Krishnamurthy (1979) 73 per cent reduction were achieved by the use of 2% Zn_3P_2 in paddy fields. Advani (1986) revealed that the application bromadiolone 0.005% and 0.002% reduced rodent populations by 79.10 and 69.16 per cent respectively, resulting in reduction of rodent damages to nuts by 78.24 and 69.53 per cent respectively.

About 95% success in killing rodents by aluminium phosphide fumigation was achieved in irrigated fields of Rajasthan by Advani and Mathur (1982). In Punjab, aluminium phosphide reduced about 80-83% of rodent burrows in rice and wheat fields (Chopra and Sood, 1983). Narendra Kumar (1988) reported 66.67% reduction in rodent population in the fields. In the present investigation Aluminium phosphide application in burrows at peg formation stage represented a percent reduction of 78 in rodent population in *Kharif*. Yield was recorded as 13.06 quintal per ha which was 3.85 quintal more than that of the control. Same treatment in *summer* obtained a percent reduction of 72 in rodent population as compared to control with an yield of 12.64 quintal per ha which was 3.64 quintal more than that of the control. Earlier studies also resulted in 76.62 per cent reduction in the rodent population in the paddy fields when each burrow was treated with 6g of aluminium phosphide (Sathisha, 1991).

In control plot the population increased from 33.33±2.89 to 81.67±2.89, from germination stage to harvesting stage with an average yield of 9.20 quintal per ha in Kharif, while rodent population increased from 38.33±2.89 to 83.33±2.89 average yield of 9.00 quintal per ha during *summer*.

With respect to the yield obtained, there was a significant difference between treatments and control. Tenth treatment [2% Zn_3P_2 baiting at germination stage + Al_2 $(PO_3)_2$ application in peg formation stage] was found to be more effective in both seasons as it shows a higher significant increase in yield than other treatments as compared to control.

5.6 Cost: Benefit ratio

In groundnut field highest cost benefit ratio of 1:38.82 in *Kharif* and 1:36.56 in *summer* obtained for the seventh (Zn_3P_2 (2%) baiting at peg formation stage) treatment followed by eighth (Al_2 $(PO_3)_2$ applications at peg formation stage) treatment where cost: benefit ratio was found to be 1 1:32.67 and 1:30.88 in *Kharif and summer* respectively for one ha area. Cost: benefit ratio was higher in sixth treatment (Bromadiolone (0.25%) CB at peg formation stage) with 1:30.59 during *Kharif* and1:28.61during *summer*.

In an earlier study, Sathisha (1991) estimated a cost: benefit ratio of 1:11.42 excluding labour cost for bromadiolone treatment in paddy field. The estimated cost and benefit ratios worked out for rodent control with different rodenticides were 1:8-1:25 in sugarcane (Ahmad and Parshad, 1987), 1:18 and 1:24 in rice (Sridhara, 1992) 1:26-1:38(Ahmad and Parshad, 1989) and 1: 247 in wheat (Advani *et al.*, 1982), 1:49 in peanut (Mittal and Vyas, 1992), 1:900 in some vegetables in the Rajasthan desert (Advani and Mathur, 1982) and 1:66-1:90 in watermelon fields (Kumar *et al.*, 1997).

Rajashekhar (2012) revealed that the cost: benefit ratio for poison baiting in ragi field with broken jowar along with Zn_3P_2 (2%) and groundnut oil (2%) was1:4.63 and in case of broken ragi was used it increased to 1:6.74, whereas cost: benefit ratio for poison baiting in soya bean field with broken jowar along with Zn_3P_2 (2%) and groundnut oil (2%) was1:6.12 and in case of broken ragi, it increased to 1:8.20.

However, the highest yield obtained in eleventh treatment (2% Zn_3P_2 baiting at germination stage followed by Al_2 $(PO_3)_2$ application in peg formation stage) with cost: benefit ratio of 1:21.88 followed by ninth (54 Snap traps application per ha at germination stage followed by 2% Zn_3P_2 baiting at peg formation stage), tenth (Bromadiolone (0.25%) CB at germination stage followed by 2% Zn_3P_2 baiting at peg formation stage) and eighth (Al_2 $(PO_3)_2$ applications at peg formation stage) treatments with cost: benefit ratios 1:10.17, 1:5.17 and 1:32.67, respectively.

VI. SUMMARY

The study on habitat burrow ecology of field rodents and their management in groundnut was carried out during both during *Kharif* and *summer* of 2012-13 in groundnut crop at Thagachuguppey village, Magadi Taluk of Ramanagara District of Karnataka state.

The study indicated that the five rodent species of the family muridae were commonly found in the groundnut fields of study area. They were Lesser bandicoot rat, *Bandicota bengalensis* (Gray)*;* Indian Gerbil, Tatera *indica* (Hardwicke); Common Indian field mouse, *Mus booduga* (Gray); Brown spiny mouse, *Mus platythrix* (Gray) and Larger Bandicoot rat, *Bandicota indica* (Bechstein).

The lesser bandicoot rat burrows were clearly marked by the presence of heaps of soil at different points along the burrow length. The soil mounds appeared in the form of "Mole hills". The mean weight of the soil thrown out was 5.55±3.1 kg. Soil mounds were noticed near the openings of the burrow of Indian gerbil. The disposed loose soil by rats was frequently noticed in the form of scattered heaps usually near the main opening and occasionally in front of all the openings in a burrow. The burrow openings were exposed without being covered by the excavated soil. Unlike other rodents burrows of *Mus spp.* was simple and shallow. The burrows could be distinguished from those of other rodent species by smaller opening of about one cm with scooped soil before the burrow opening.

The presence of fresh soil heap near an opening of burrow of *B. bengalensis* was considered as the main entrance of the burrow. The burrows were kept sealed, perhaps to prevent the entry of snakes and prevent desiccation. The presence of large scattered heap of soil in front of an opening which always had a larger diameter was considered to be

main entrance of Indian gerbil. The presence of *M. booduga* in burrows could be ascertained by the degree of freshness or wetness of pellets at the entrance. *M. platythrix* exhibited a peculiar behaviour of pebble collection around the surface openings.

The surface openings of lesser bandicoot rat burrows were externally covered by the excavated soil heaps. The openings were sealed on the surface with the packing of loose soil and packing was not usually hard. The mean numbers of openings observed were 3.76±1.29 and range was 1-4. Mean number openings of *T. indica* was 2.59±0.54 and the mean diameter was 6.10±0.74. Study also revealed that the mean numbers of openings and mean diameter were 1.50±0.53 and 2.32±0.29 for *M. booduga and* 1.84±0.56 and 3.25±0.08 for *M. platythrix*, respectively.

The mean numbers and mean diameter of side tunnels present during the cropping seasons and off seasons were 3.36±1.01 and 7.07±0.77 cm for *B. bengalensis* and 2.13±0.54 and 3.61±0.30 for *T. indica,* respectively. The mean numbers of tunnels in *M. booduga* and *M. platythrix* was 0.5±0.92. Mean diameter of tunnel were 2.53±0.20 and 2.33±0.18, respectively. The mean numbers of tunnels in *B. indica* burrows was 3.37±0.25 and mean diameter of tunnel was 12.75±0.35.

The present investigation revealed that maximum depth of the burrow of *B. bengalensis* was 89 cm and that of Indian gerbil was 44 cm. Maximum depth of the burrow recorded was 18 cm and 38.6 cm for *M. booduga* and *M. platythrix*, respectively whereas B. *indica* burrows recorded a maximum depth of 112.5 cm.

During excavation the maximum total length of the burrow recorded were 753 cm and 390 cm for *B. bengalensis* and *Tatera indica,* respectively. In *M. booduga* the maximum total length of the burrow ranged from 35 to 129 cm. Total length of *M. platythrix* burrow was ranged from 75cm to 145cm.

Male and female rats of *B. bengalensis* stored large quantities of food grain in the burrows. The quantity of groundnut hoarded was found to be 36.24±39.06 g per burrow. Indian gerbils also stored good quantities (52.09±56.47 g) of food in the food chamber especially during summer season. The burrows of *M. booduga, M. platythrix and B. indica* did not contain any hoarded material except a few leaves and straw of the neighbouring crops.

Young ones of the *B. bengalensis* were found during peg formation and harvesting stages of kharif and summer seasons. When the burrows were dug the unfurled young blind rattling's noticed within brood chamber. For *T. indica* the maximum numbers of litter size noticed were twelve. It was found to be five for *Mus spp.* and no litters were found in B. indica burrows.

Proportion of *B. bengalensis* in the field was more irrespective of crop stages and seasons with the percentage distribution of 43.1 followed by *T. indica*, *M. booduga, M. platythrix* and *B. indica* with 31.99, 12.73, 10.25 and 1.86 per cent, respectively. Percentage distributions of rodent burrows within the field, on bunds and up to 10m away from bunds were 10.87, 33.22 and 55.90, respectively.

During the present investigation, it observed that rodent damage in groundnut occurred from the sowing stage to harvesting of crop both in *Kharif* as well as *summer*. The maximum percentage damage by rodents in groundnut during *Kharif* season was 19.38 and that in *summer* was 21.79 during harvesting period.

There was a significant reduction of live burrow counts due to treatments.

Among the treatments best was T_{11} (2% Zn_3P_2 baiting at germination stage + Al_2 $(PO_3)_2$ application in peg formation stage) which recorded 82 per cent reduction in live burrows which is on par with T_9 (54 Snap traps per ha at germination stage+2% Zn_3P_2 baiting at peg formation stage) with 80 per cent reduction followed by T_8 (Al_2 $(PO_3)_2$ application in burrows at peg formation stage), T_{10} (Bromadiolone (0.25%) CB at germination stage + 2% Zn_3P_2 baiting at peg formation stage) and T_{12} (2% Zn_3P_2 baiting at germination stage + Bromadiolone (0.25%) CB at peg formation stage) all with 78 percent reduction of live burrow counts during kharif compared to control.

The highest yield of 1381kg/ha was also recorded in T_{11} followed by T_9 (1363.65 kg/ha), T_{12} (1335.19 kg/ha), T_{10} (1321.71 kg/ha) and T_8 (1306.11 kg/ha). However, the C:B ratio was highest (1:38.12) in T_7 with yield of 1281.09 kg/ha followed by T_8 and T_6 with C:B ratio of 1:32.67 and 1:30.59 with a yield of 1306.11 and 1229.63 kg/ha, respectively.

Similarly in *summer* season best treatment was T_{11} (2% Zn_3P_2 baiting at germination stage + Al_2 $(PO_3)_2$ application in peg formation stage) which recorded 76 per cent reduction in live burrows which is on par with T_9 (54 Snap traps per ha at germination stage+2% Zn_3P_2 baiting at peg formation stage) with 74 per cent reduction followed by T_8 (Al_2 $(PO_3)_2$ application in burrows at peg formation stage), T_{10} (Bromadiolone (0.25%) CB at germination stage + 2% Zn_3P_2 baiting at peg formation stage) and T_{12} (2% Zn_3P_2 baiting at germination stage + Bromadiolone (0.25%) CB at peg formation stage) all with 72 percent reduction of live burrow counts compared to control.

The highest yield of 1351.33kg/ha was also recorded in T_{11} followed by T_9 (1328.17 kg/ha), T_{12} (1308 kg/ha), T_{10} (1283.21 kg/ha) and T_8 (1264.06 kg/ha). However, the C:B ratio was highest (1:36.56) in T_7 with yield of 1239.11 kg/ha followed by T_8 and T_6 with C:B ratio of

1:30.88 and 1:28.61 with a yield of 1264.06 and 1190.19 kg/ha, respectively.

Future line of work

1. The excavation of burrows has to be done in varied climates and crops in order to find out a clear cut picture of burrows of each species as the burrow structure varies with respect to adaptic factors, cropping pattern and season.

2. In depth study is essential on the spatial distribution of rodents, in varied conditions.

3. There is a need to evaluate new rodenticides.

VII. REFERENCES

ADVANI, R., 1986, Field evaluation of single and multiple dose anticoagulant rodenticides in reducing rodent populations and damages in coconut plantations. *Proceedings of the Twelfth Vertebrate Pest Conference*, Lincoln, University of Nebraska. pp.162-172.

ADVANI, R. AND MATHUR, R. P., 1982, Experimental reduction of rodent damage to vegetables crops in Indian villages. *Agro-Ecosystems*, **8**: 32-46

ADVANI, R., PRAKASH, I. AND MATHUR, R. P., 1981, Rodent control in Jodhpur. *Indian Farming*, **32**: 9-11.

ADVANI, R., PRAKASH, I. AND MATHUR, R. P., 1982, Assessment of rodent damage and field losses in standing wheat crop in a desert village complex. *Z. Angew. Zool.*, **99**: 257-66.

AHMAD, N. AND PARSHAD, V. R., 1987, Rodent control in sugarcane. *Sugar Cane* **, 87**: 3–6.

AHMAD, N. AND PARSHAD, V. R., 1989, Effect of size of baiting area on rodent control success with bromadiolone in wheat crop. *Indian J. Plant Prot.*, **17**: 1-4.

AHMAD, S., PANDIT, R. K. AND BROOKS, J. E., 1994, Post-harvest grain losses in farm houses in Bangladesh: Rodent population estimates and potential stored paddy losses. *DWRC Res. Rept. No.* 11-55-003. pp. 13.

AINP, 2010, Annual Progress Report of All India Network Project on Rodent Control (2009-2010), University of Agricultural Sciences, Bangalore,India pp. 89.

AMUSA, N. A., IKEN, J. E. AND FYENUWO, J. O., 2005, The incidences of field diseases and vertebrate pest on pop corn (*Zea mays Everta*) varieties cultivated in agro forest ecologies in Nigeria. *World J. Agric. Sci.*, **1**: 173-177.

ANONYMOUS, 1984, Annual Progress Report (1983-84) of AINP on Rodent control, Punjab Agril. Univ. Ludhiana,India

ANONYMOUS, 1990, Annual Progress Report (1983-84) of AICRP on Rodent control, Gujarat Agril. Univ. Junagadh, India

ANONYMOUS, 1991, Report of the second quinquennial review team 1985–89: All India Network Project on Rodent Control, Indian Council of Agricultural Research, New Delhi, p. 45.

APLIN, K. P., FROST, A., TUAN, N. P., HUNG, N. M. AND LAN, L. P., 2003, *Notes on the taxonomy and biology of rodents of the genus Bandicota in Southeast Asia*. In: Singleton, G.R., Hinds, L.A., Krebs, C.J. and Spratt, D.M., (eds), Rats, mice and people: rodent biology and management. ACIAR Monograph No. 96. Canberra, Australian Centre for International Agricultural Research, pp. 531-535.

ARJUNWADKER, A.V. AND GADGIL, M., 1974, Burrowing habits of the greater bandicoot rat (*Bandicota indica*). *J. Bombay nat. Hist. Soc.*, **71**: 1138-140.

BARNETT, S. A. AND PRAKASH, I., 1975, *Rodents of economic importance in India.* Arnold Heinemann Publ., New Delhi. p. 185.

BHADURIA, A. S. AND MATHUR Y. K., 1993, Burrow patterns of bandicoot rat, *Bandicota bengalensis* (Gray). *J. Ent. Res.,* **17**: 267-273.

BHAT, S. K. AND SUJATHA, A., 1991, Population structure and breeding season of the field mouse, *Mus booduga* Gray. Mammalia, **55**: 389-396.

BINDRA, O. S. AND SAGAR, P., 1975, A review of studies on the ecology, biology, damage and control of field-rats and field-mice in the Punjab. *Proc. All India Rodent Seminar,* Ahmedabad, pp. 82–8.

BISWAS, B. AND TIWARI, K. K., 1969, Taxonomy and distribution of Indian rodents. **In**: K.L. Harris (ed) *Proc. Indian Rodent Symp.,* Calcutta, pp. 9–45.

BUTANI, S. R., 2006, Evaluation of second generation anticoagulants in groundnut crop. *Pestology*, **12**: 28-32.

CHAKRABORTY, S., 1975, Field observations on the biology and ecology to the lesser bandicoot rat, *Bandicota bengalensis* (Gray) in West Bengal. *Proc. All India Rodent Seminar,* Ahmedabad, pp. 102–112.

CHAKRABORTY, R., 1985, Eco-toxicology of the Large Bandicoot Rat, *Bandicota indica* (Bechstein) [Rodentia: Muridae]. *Ph.D. Thesis*. Univ. of Calcutta.

CHAKRABORTY, R., 1992, The large bandicoot rat, *Bandicota indica* (Bechstein). In: Prakash, I. and Ghosh, P. K. (eds), Rodents in Indian agriculture, volume 1. Jodhpur, India, Scientific Publishers, pp. 193- 210.

CHAKRAVARTHY, A. K., 1993, Vertebrate Pest Management on cardamom and other crops in Malnad Region: Final project report. Indian Council of Agricultural Research, New Delhi. pp. 54.

CHANDANA, S. S. AND GARG, S. K., 1982, Studies on the burrowing and breeding habits of the Indian field mouse, *Mus booduga* (Gray). *Indian J. Rodent*. **4**: 19-27.

CHANDRAHAS, R. K., 1974, Ecology of brown spiny mouse, *Mus platythrix* (Bennet) and the Indian field mouse, *Mus booduga* (Gray). *Indian J. Med. Res.*, **62**: 971-978.

CHANDRAHAS, R. K. AND KRISHNASWAMY, A. K., 1974, Studies on the ecology of the Indian gerbil, *Tatera indica* (Gray) in Kolar, (Karnataka state). *Indian J. Med. Res.*, **62**: 971-978.

CHATTOPADHYAY, D., MADHU, N. R. AND MANNA, C. K., 2010, Burrowing pattern and damage caused by the rodent pest, Indian house rat (*Rattus rattus*) in the Gangetic and Non Gangetic plain of West Bengal, India. *Univ. J. Zool.,* Rajshahi. Univ., **28**: 57-60.

CHAUDHARY, V. AND TRIPATHI, R. S, 2010, Incidence of rodent pests in Cumin (*Cuminum cyminum* L.) and their management. *J. Hortl. Sci.*, **5**: 64-67.

CHOPRA, G. AND SOOD, M. K., 1983, Laboratory evaluation of Bromadiolone against *Bandicota bengalensis*. *Pestology*, **9**: 21-22.

COLANGELO N. K., 2005, A study on Indian rodent taxa in Indo-Pakistan subcontinent. *Mammalia*, **85**: 54-59.

CUONG L. Q., CHIEN H. V., DUC V. H. AND SINGLETON, G. R., 2002, Relationship between rodent damage and yield loss in rice in Mekong Delta. In: Singleton G. R., Hinds, L. A., Krebs C. J. and Spratt, D. M. (eds), Rats, mice and people: rodent biology and management. Canberra (Australia): Australian Centre for International Agricultural Research, 297-300.

DEORAS, P.J., 1966, Some observations on the probable damage caused by rats in Bombay. *Ind. J. Ent.*, **28**: 543-547.

DUBOCK, A. C., 1980, The development and practical use of the novel anticoagulant rodenticide brodifacoum. *Plant Prot. Bull.*, **20**: 223-238.

DURAIRAJ, G. AND GURUPRASAD, B. K., 1975, Demographic studies of *Bandicota bengalensis* in the paddy fields of Mysore district (Karnataka). Proc. All India Rodent Seminar, Ahmadabad, pp 126-128.

FAYENUWO, J. O., OLAKOJO, S. A., AKANDE, M., AMUSA, N. A. AND OLUJIMI, O. A., 2007, Comparative evaluation of vertebrate pest damage on some newly developed quality protein maize (QPM) varieties in South Western Nigeria. *Afri. J. Agric. Res.,* **2**: 592-595.

FRANK, J. H., 1970, Rats and sugarcane. *Sugarcane Bull. Res.* Dept. of the *Sug. Manufr. Assoc. of Jamaica*, **1**:1-2.

GOVINDA RAJ, G., 1994, Effective period for the control of brown spiny field mouse (*Mus platythrix*) in dry land crops. *Proceedings of 16th vertebrate conference*, USA. pp. 95-100.

GOVINDA RAJ, G. AND SRIHARI, K., 1987, Effective period for the control of gerbils, in dry land crops: A study based on reproductive biology. *Zeiteschrift fur Augewarolte Zoologie*, **74**: 134-231.

GOYAL, S. P. AND GHOSH, P. K., 1993, Burrow structure of two gerbil species of Thar desert, India. *Acta Theriologica,* **38**: 453 – 456.

GREAVES, J. H., GEORGE, W. F. AND KHAN, A., 1975, Preliminary investigations of the Rice-Rat problem in Lower Sind. *Proc. All India Rodent Seminar*, Ahmadabad, pp 24-28.

HOPF, H. S., MORELEY, G. E. J. AND HUMPHRIES, J. R. O., 1976, Rodent damage to growing crops and to farm and village stores in tropical and sub-tropical regions. *Centre for Overseas Pest Res.*, p. 115.

HOOD, G. A., 1972, Zinc phosphide- a new look at an old rodenticide for field rodents. Proceedings of the Vertebrate Pest Conference University of California. USA, pp. 85-92.

IDRIS, M., PRAKASH, I. AND RANA, B. D., 2002, Some observations on infestations of field mouse in the forest nursery of arid region. *Rodent Newsl.*, **25**: 5-10.

JAIN, A. P., 1970, Body weights, sex ratio, age structure and some aspects of reproduction in the Indian gerbil, *Tatera indica indica* (Hardwicke) in Rajasthan desert, India. *Mammalia,* **34**: 415-432.

JARVIS, M. M. AND SALE, S. P., 1971, Burrow pattern of field rats in South India. *J. Hyg. Camb.*, **79**: 190.

KALYAN, B. S. AND CHANCHAL, K. M., 2008, Studies of some aspects of rodent ecology in the four districts of the Gangetic plain of West Bengal, India. *Univ. J. Zool.* Rajshahi Univ., **27**: 85-90.

KASEM, T., 1980, Efficacy tests of different rodenticides on some species or rats in Thiland. *Proceedings of the 9th Vertebrate Pest Conference*, Lincoln, University of Nebraska. pp. 143-145.

KHAN, A. A., 1977, Development of sugarcane rat control programme by Fauji Foundation Sugar Mills, In: *Proc. 14th Conf. Pak. Soc. Sug. Technol.*, Karachi. pp. 108-115.

KHAN, A. A., 2007, Comparative evaluation of two anticoagulant and two acute rodenticieds in sugarcane fields. *Sarhad J. Agric.*, **23**: 713-718.

KHAN A. A., HUSSAIN I. AND MUNIR S., 2009, Control of rodent damage to groundnuts in the Pothwar Plateau Region of Pakistan. *Pakistan J. Zool.,* **41**: 203-207.

KUMAR, P., PASAHAR, S. C., SABHLOK, V. P., SINGHAL, R. K. AND KUMAR, P., 1997, Efficacy and economics of rodenticides for rodent management in watermelon (*Citrullus lanatus*) fields. *Indian J. Agic. Sci.*, **67**: 528-530.

KUMAR, P., KUMAR, A. S. AND RAO, A. M. K., 2009, Bio-efficacy of Aluminium phosphide tablets against *Bandicota bengalensis* in rice fields around Hyderabad. *Rodent Newslett.*, **33**: 26-27.

MALHI, C. S. AND PARSHAD, V. R., 1987, Pest damage to harvested wheat and paddy. *Indian Farm.* **37**: 29–30.

MALHI, C. S., PARSHAD, V. R. AND CHOPRA, G., 1987, Burrowing behavior of *Mus platythrix. Mammalia*, **51**: 51-58.

MANN, G. S. AND BINDRA, O. S., 1974, A note on the effectiveness of poison baiting of field rats and field mice in wheat fields, *Indian J. Pl. Prot.*, **1**: 64-65.

MANU, S. K., 2010, Rodent damages in oilseed crops in South India. *Rodent Newslett.*, **37**: 29-35.

MAQBOOL, S., KHAN, A. A. AND SIDDIQUE, M., 2011, Burrowing characteristics and food hoarding behaviour of *Bandicota bengalensis* in wheat fields of Jammu and Kashmir and Pakistan. *Pakistan J. Zool.*, **43:** 987-992.

MARSH, R. E., 1977, Bromadiolone, a new anticoagulant rodenticide. *EPPO Bull.,* **7**: 497-502.

MATHUR, R. P. AND PRAKASH, I., 1981, Evaluation of brodifacoum against *T. indica*, *M. hurrianae* and *R. rattus*. *J. Hyg. Camb.*, **87**:179.

MITHAL, S. S., 1987, Extend of rodent damage in major crops in South India. *Acta Theriologica,* **46:** 493 – 496.

MITTAL, V. P. AND VYAS, H. J., 1992, Groundnut. In: Prakash, I. and Ghosh, P. K. (eds.), *Rodents in Indian Agriculture*, Scientific Publishers, Jodhpur. pp. 249-264.

MOHAN RAO, A. M. K.1979, A report on rodent population in cyclone affected area in Andhra Pradesh. *Rodent Newsl.*, **2**: 5-6.

MUKTHABAI, K. AND MAJUMDER, S. K., 1989, Toxicity of calciferol, warfarin and their combinations to *Rattus norvegicus* and *R. rattus*. *Pesticide Sci.,* **9**: 44-50.

NARENDRAKUMAR, J. B., 1988, Studies on food preferences and bait shyness in larger bandicoot rat (*Bandicota indica* Bechstein). *M. Sc. Thesis*, University of Agricultural Sciences, Bangalore, India.

NEENA, S. AND PARSHAD, V. R., 2010, Efficacy of acute and anticoagulant rodenticide baiting in sugarcane fields of Punjab, India. *Int. J. Pest Mgmt.*, **56**: 201-210.

NEENA, R., SINGLA.V. AND VIR PRASAD, M., 2010, Efficacy of acute and anticoagulant rodenticide baiting in sugarcane fields of Punjab. *Int. J. Pest Mgmt.,***13**: 41-43.

PARSHAD, V. R., 1999, Rodent control in India. *Integrated Pest Mgmt. Reviews*, **4**: 97:126.

PARSHAD, V. R., MALHI, C. S., AHMAD, N. AND GUPTA, B., 1987, Rodent damage and control in peanut fields in India. Peanut Sci., **14**:4-6.

PATEL, N. C. AND NAYAK, N. P., 1987, Survey of various stored grain and field pests for all crops: Final Report of RPF III, All India Co-ordinated Scheme for Harvest and Post Harvest Technology, Junagadh, Gujarat Agril. Univ.

PRADHAN, M. S. AND TALMALE, S. S., 2011, A checklist of valid Indian rodent taxa. *Mammalia*, **83**: 74-79.

PRAKASH, I., 1975, The population ecology of rodents in the Rajasthan Desert, India. In :Rodents in Desert Environments, *Rodentia* , pp. 75-116.

PRAKASH, I. AND MATHUR, R. P., 1987, *Management of Rodent Pests*, ICAR, New Delhi, p.133.

PRAKASH, I., JAIN, A. P., AND PUROHIT, K. G., 1971, Breeding and post-natal development of the Indian gerbil, *Tatera indica indica* Hardwicke in Rajasthan desert. *Saugt. Mitteil*, **19**:99-115.

PRASAD, M. R. N., 1961, Reproduction in female Indian gerbil, *Tatera indica* (Waterhouse), *Acta Zool.*, **42**: 245-256.

PRATER, S. H., 1971, The Book of Indian Animals. *J. Bombay nat. Hist. Soc.,* Bombay. **43**: 263-272

PRODIP K. S. AND PARIMAL, B., 2012, Study on Rodent Diversity in and around Marat Longri Wildlife Sanctury, Karbi Anglong Distict of Assam, India. *Sci. Probe,* pp.14-20.

PUANGTONG, B. AND GREANGSAK, H., 1998, Preliminary study assessing integrated rodent management strategies for soybean crops in Thailand. *In*: *Proceedings national soybean research conference VII*, Sukhothai Thammathirat Open University, Bangkok (Thailand), pp. 370-378.

RAJASEKHARAN, M. R., AND DHARMARAJU, E., 1975, Studies on field rodents in Andhra Pradesh. *Proc. All India Rodent Seminar*, Ahmadabad. pp. 54-55.

RAJASHEKHAR, B. N., 2012, Studies on population dynamics and management of rodents in soybean-ragi ecosystem, *M.Sc(Agri.)Thesis*, University of Agricultural Sciences, Bangalore, India

RAM MANOHAR, 2001, Extend of damage caused by rodents in oil seed crops. *J. Bombay nat. Hist. Soc.,* Bombay, p. 189.

RANA, B. D. AND ADVANI, R., 1981, Food composition of the metad, *Rattus meltada* Pallidor in Western Rajasthan. *Acta Theriol.*, **26**: 129-132.

RAO, A. M. K. M., 1980, Demography and hoarding among lesser bandicoot rat, *Bandicota bengalensis* in the rice fields. *Saug. Mitteil*, **28**:312-314.

RAO, A. M. K.M., 2011, Damages caused by rodents in groundnut crop. *Curr. Res.*, **6**: 217-219.

RAO, A. M. K. M., PURUSHOTHAM, K. R. AND RAJABAI, B. S., 1977, Bait for the control of India field mouse, *M. booduga*. *Z. angew. Zool.* **65**:163-171.

ROBERTS, T. J., 1977, *The mammals of Pakistan*, Earnest Benn Ltd, London. p.189.

ROMERO, A. G., SANDOVAL, G. T., SERNASECUNDINO, J. AND AGUILARRAMIREZ, V. M., 1978, Damages caused by cotton rat, *Sigmodon hispidus zanjonensis*, on sugar cane In San Pedro Sula, Honduras. *Proceeding of the 8th Vertebrate Pest Conference*, Lincoln, University of Nebraska. pp. 231-236.

ROY, S. K., 1974, Preharvest loss of rice due to field rodents. *Econ. Political Wkly.*, **9**: 66-67.

SATHISHA, N. S., 1991, Evaluation of baits selected rodenticides for the control of *Rattus meltada* (*Millardia meltada*). *M.Sc. Thesis*, University of Agricultural Sciences, Bangalore.

SHAH, M. P., 1979, Population explosion of rodents in groundnut fields in Gujarat. *Rodent News letter.*, **3**:19-20.

SHAKUNTALA, A. S., 1976, Burrow pattern of *Bandicota bengalensis* Gray in the paddy field of Karnataka. *Curr. Res.*, **5**:207-209.

SHEIKER, C. AND JAIN, S. D., 1991, Damage and hoarding by rodents and their control in standing wheat in Himachal Pradesh. *Trop. Pest Mgmt.*, **37**:298-300.

SHEIKER, C. AND MALHI, C. S., 1983, Territorial and hoarding behaviour in *Bandicota* sp. and *Mus* sp. of Garhwal Himalayas. *Proc. Indian Natn. Sci. Acad.* **49**: 332–335.

SINGH, S. M., HARRIS, H. M. AND BATRA, H. N., 1965, Campaign against rats taken up in the Hathras block, I. A. D. P. block, district Aligarh (U.P.). *Pl. Prot. Bull.* **17**: 30-33.

SINGLA, N. AND BABBAR, B. K., 2010, Rodent damage and infestation in wheat and rice crop fields: district wise analysis in Punjab State. *Indian J. Ecol.*, **37**:184-188.

SOOD, M. L. AND UBI, B. S., 1975, Population fluctuations of sympatric murids occuring in the field of PAU, Ludhiana. 1. Effects of biotic factors. Proceedings of the All-India Rodent Seminar, Ahmadabad, pp. 76-81.

SOOD PANKAJ, P. AND CHAND PREM, U., 2007, Burrow pattern of lesser bandicoot rat, *Bandicota bengalensis* (Gray) in Himachal Pradesh. *Agri.Sci. Dig.*, **27**: 307-308.

SRIDHARA, S., 1992, Rice. In: Prakash, I. and Ghosh, P. K. (eds), *Rodents in Indian Agriculture*, Scientific Publishers, Jodhpur, India, pp. 254.

SRIDHARA, S., 1999, A study on rodent damage in groundnut crop in Southern states in India. *Rodent Newslett.,* **39**: 5-9.

SRIDHARA, S. AND KRISHNAMURTHY, R. V., 1979, Efficacy of three rodenticides in paddy fields*. Z. Angew. Zool.,* **66**:233-242.

SRIDHARA, S. AND SRIHARI, K., 1980, Food hoarding behaviour of *Tatera indica cuvieri* captivity*. Mysore J. Agri. Sci.*, **13**: 56-58.

SRIDHARA, S. AND TRIPATHI, R. S., 2005, Recent trends in Coordinated Research on Rodent Control. *Rodent Newslett.,* **34**: 2-4.

SRIHARI, K. AND GOVINDA RAJ, G., 1988, Effective period for the control of *Bandicota bengalensis* in paddy fields. *Tropical Pest Management*, **34**:141-146.

SRIDHARA, S., KRISHNAMURTHY, R. V. AND KRISHNAMOORTHY, T. R., 1979, Bait shyness in the bandicoot, Bandicota bengalensis, *Indian J. exp. Biol.* **21**:560-563.

SRIHARI, K., SRIDHARA, S. AND COWAN, P. E., 1979, Toxicity of zinc phosphide to *Bandicota bengalensis*, *Mysore J. Agri. Sci.*, **13**:57-59.

SRINIVAS RAO, N. AND NANDA KISHOR, M., 2009. Seasonal changes in the population size and reproduction of *B. bengalensis* in rice-rice-pulse ecosystem in Andhra Pradesh. *Indian J. Pl. Prot.*, **37**:59-63.

SRIVASTAVA, A. S., 1968a. Rodent control for increased food production. Rotary Club (West), Kanpur. p.152.

SRIVASTAVA, A. S., 1968b. Dynamics of population of field rats in relation to the live burrows. *Mammalia.*, **32**:164-171.

SRIVASTAVA, A. S., 1970c. Project Coordinators Final Report on the All India Coordinated Scheme for Research on the study of field rats (1959-69). New Delhi, ICAR, pp. 1-147.

STAPLES, L., SMITH, M. AND PONTIN, K., 2003, Use of zinc phosphide to overcome rodent infestations. In: Wright, E. J., Webb, M. C., Highley, E., editors. *Proceedings of the Australian Postharvest Technical Conference*, Canberra: Stored grain in Australia, CSIRO Stored Grain Research Laboratory. pp. 110-115.

SUNITA S., CHEONG N., NARAYAN, G. AND SHARMA T., 2009, Burrow characteristics of the co-existing sibling species *Mus booduga* and *Mus terricolor* and the genetic basis of adaptation to hypoxic/hypercapnic stress. *BMC Ecology,* ***9****:6.*

TITHIPARAMOTE, N., 2009, Reproductive biology of greater bandicoot rat, *Bandicota indica* in rice in Southern Thailand. *Curr. J. Zool.,* **55**:48-55.

TRIPATHI, R. S., 2007, Recent trends in Coordinated Research on Rodent Control. *Rodent Newslett.,* **31**:1-4.

URS, Y. L., KRISHNAKUMARI, M. K. AND MAJUMDAR, S. K, 1966, A report on the burrowing habit of rodents. *Indian Rodent Symp.*, Calcutta. pp. 199-203.

YIGGIT, N., COLAK, E. AND VERIMLI, R., 2001, A study on the distribution, morphology and karyology of *Tatera indica* (Hardwicke, 1807) (Mammalia: Rodentia) in Turkey. *Turk. J. Zool,* **25**: 67-70.

APPENDIX

Estimation of cost: benefit ratio (For 1 ha):

Snap trap	= 54	Cost of snap trap	= Rs. 1080
Zn_3P_2	= 20 g	Cost of Zn_3P_2	= Rs. 14
Bromadiolone	= 25g	Cost of Bromadiolone	= Rs. 25
$Al_2 (PO_3)_2$	=6 tablets	Cost of $Al_2 (PO_3)_2$	= Rs. 6

Labour cost (@ 1 labour/ha) = Rs. 200

Ragi	=440 g	= Rs.11
Rice	=440 g	= Rs. 24.60
Groundnut Oil	= 50 ml	= Rs. 12
Groundnut powder	= 50g	= Rs. 8
Total cost of pre bait		= Rs. 47.60

Rate of groundnut per Qtl. = Rs. 3500