

# Integrated Rodent Pest Management in Rice



**ALL INDIA NETWORK PROJECT ON  
VERTEBRATE PEST MANAGEMENT (ICAR)**

**Acharya N G Ranga Agricultural University,  
Regional Agricultural Research Station, Maruteru - 534122**



# All India Network Project on Vertebrate Pest Management Regional Agricultural Research Station

Maruteru- 534122, West Godavari Dist., Andhra Pradesh

Technical Bulletin Number 4

Published on: July 2021

Authors:

**Dr. Namala Srinivasa Rao**, Senior Scientist (Entomology)

**Smt. Bonku Anusha**, Scientist (Entomology)

**Dr. Vipin Chowdhary**, Network Co-Ordinator, CAZRI, Jothpur

**Dr. Moka Nanda Kishore**, Principal Scientist (Entomology)

**Dr. ADVSLP Anand Kumar**, Scientist (Entomology)

Published by:

**Dr. G. Jogi Naidu,**

Associate Director of Research, RARS, Marteru

Copies: 1000

Printing: Icon Designers, Hyderabad

# CONTENTS

<b>S. No.</b>	<b>Chapter title</b>	<b>Page No.</b>
1	Introduction	
2	Rodent pest species attacking rice	
3	Nature of rodent damage in rice	
4	Rodent survey and surveillance	
5	Rodent pest management methods s in rice	
	a) Cultural methods	
	b) Physical and mechanical methods	
	c) Ecological methods	
	d) Biological methods	
	e) Chemical methods	
6.	Rodenticide application techniques	
7.	Integrated Rodent Management	
8.	Future thrust and conclusion	



# Foreword



# Message



# Message



# Preface



# Integrated Rodent Pest Management in Rice

## I. Introduction:

Rice is the staple food crop for over 3 billion people in the globe and is a major cereal in India meeting dietary requirement of nearly 70% of country's population. Rice is cultivated in an areas of 43.79 million hectares with a production of 112.9 million tons of milled rice with an average productivity of 3.38 t/ha in the country. Major rice growing states of India are West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Orissa, Bihar and Chhattisgarh accounting more than 75% of the total rice production in the country. Andhra Pradesh is the rice bowl of the country with a production of 93.23 lakh tons of milled rice from 23.56 lakh hectares. Among various biological constraints in rice cultivation, rodents are one of the major concern, causes considerable damage to rice crop in India irrespective of the type of rice production system viz., irrigated, wetland or upland. The rodents can attack rice plants throughout their growth periods i.e. from seedling to harvesting. However, the attack intensifies during maximum tillering, when the rice canopy becomes dense.

Rice growing coastal areas of Andhra Pradesh, particularly Godavari and Krishna delta, became endemic to rodent pests in rice based ecosystems, due to Rice-Rice-Pulses cropping pattern, which provided continued availability of food and shelter for rodent pests. Further, deltaic alluvial soils which are bulky and soft found highly conducive for making burrows easily by these fossorial rodents. In addition, increased irrigation facilities contributed to increased crop productivity thereby more food availability to the rodent resulting in increased breeding and populations. An estimate made by erstwhile All India Coordinated Research Project in Rodent Control, which is now named as All India Network Project on Vertebrate Pest Management (AINP on VPM-ICAR Project) at AP Rice Research Institute, Acharya N.G. Ranga Agricultural University, Maruteru estimated the rodent damage to rice as 15.9% in West Godavari, 10.45% in East Godavari, 10.42% in Krishna and 8.34% in Guntur districts. The studies conducted by AINP on VPM indicated that the overall tiller damage to rice crop ranged from 9.56 to 60.8% during kharif and 0.42 to 30.9% in rabi crop. As per these reports and assuming a moderate loss of 10% in Rice due to rodent pests the production loss would be around 1.5 m. tones out of 15 m. tones of total production of the state every year. The financial implications of yearly minimum losses come to around Rs. 15,000 million in the case of rice production and the losses will be more than the above in the years of rodent outbreaks.

Rice growing Godavari and Krishna deltas of Andhra Pradesh had a history of rodent outbreaks due to flash floods during 1977, 1988, 1996 and 2009, when the rodent population has increased alarmingly after the flash floods, which removes part of the rodent population leading to compensatory increased breeding by surviving ones, thus culminates in to population explosion causing extensive damage to rice crop. In addition, the farmers of Godavari delta districts with East and West Godavari often experienced minor rodent outbreaks one season after comparatively lesser flash floods. The duration of the major rodent outbreaks was found to be 10 years, while those of minor outbreaks to be



at 3-5 years. During 2009-10, DOA has declared crop holiday for rice in certain mandals of Godavari districts due to shortage of irrigation water and low market prices. In crop holiday mandals farmers has raised the short duration pulse crop in certain pockets. Rice cropped areas in this region has witnessed the major rodent outbreak in this year. The situation analysis made by the project scientists revealed that this was happed due to two reasons; flash floods that caused abnormal breeding in rodent and rodent immigration from crop holiday/ pulse crop into the cropped areas. Farmers lost both pulse and rice crop by 50-100 per cent due to explosion of bandicoots.

## II. Rodent Pest Species Attacking Rice

Lesser bandicoot, *Bandicota bengalensis* (up to 90%) followed by *Mus booduga* (below 10%) were the predominant pest rodent species associated with rice crop in this region and India. In Godavari delta and other rice growing deltas of Andhra Pradesh, lesser bandicoots are the major culprits inflicting the damage in rice and other irrigated crops. Occasionally larger bandicoot, *Bandicota indica* also find place in the rice ecosystem, but in very few numbers. The field mouse, *Mus booduga* was also commonly seen rodent species in rice and other crop ecosystems, though their numbers found in high, the damage inflicted by them was less than 10% of the total rodent damage in rice. In field experiments of rice research station, the coconut rat/house rat, *Rattus rattus* was trapped into the multi catch traps that were laid in rice crop. This supports the ever since farmer's claim that tree rats also do considerable damage to rice crop, which often not agreed by the scientific community. This could be possible as most of rice field bunds occupied with coconut trees in this region and animal migration is quite possible from crop to crop for want of food.

### 2.1. Lesser bandicoot rat, *Bandicota bengalensis*

The lesser bandicoot is robust with a round head and a broad muzzle weighing 200-350g. The body is covered with coarse fur which forms black-tipped piles on the dorsal side. The colour on the dorsal side is dark brown but may be blackish, pale brown or reddish. Feet are dark but digits are paler. Tail is completely dark and paler below occasionally. Belly grey or light grey and rarely whitish. It is widely distributed throughout India, Pakistan, Nepal, Bhutan, Bangladesh, Sri Lanka and South East Asia. The lesser bandicoot rat is a fossorial animal an is well adapted to various habitats and ecological conditions which include cultivated fields, pastures, forests, mountains, inter-tidal mangrove zones, semi arid zones and also as a commensal in towns and cities across India. It also breeds throughout the year, with a definite peaks occur during different seasons across the country. The litter size ranges between 4-12. In rice, *B. bengalensis* remains fecund throughout the year with higher reproductive activity synchronising the reproductive phase of the crop i.e., March during rabi and Oct-Nov during kharif. The mean population growth estimates over the years indicated that, in general *B. bengalensis* could breed 2.7 and 2.45 times/season with seasonal productivity of 31 and 27 young ones/female during kharif and rabi, respectively. Among the various weather parameters rainfall plays a pivotal role on the incidence of *B. bengalensis* in rice ecosystem.



### 2.2. Larger bandicoot rat, *Bandicota indica*

It is a very large rat, head and body normally ranging 200 mm-366 mm. Weight ranges from 500 g to 2 kg and more. Tail is shorter than head and body and is covered with hair throughout its length. The fur is

very rough and quite long dorsally. The upper part of the body is dark or blackish brown and ventrum is grey, drab or dark. In India its distribution ranges from south of Rajasthan down to southern tip of India and eastwards too. The species is widely distributed in Bangladesh, Myanmar, Malaysia, Thailand, Vietnam, Sumatra, Java, southern China, Hong Kong, Taiwan and Sri Lanka. The larger bandicoot always lives close to human habitat but never inside the house or inside crop fields. It prefers habitat that has lot of garbage to feed and close to water bodies. They prefer places close to human dwellings such as compounds, gardens, stables, and poultry and out houses. The species is nocturnal and fossorial. Burrows are found amidst tall grasses and bushes around marshy areas, many a times tunnelled through bricks and masonry of poorly constructed houses and huts in villages. Burrows are simple consisting of an unbranched tunnel upto 700 cm in length and 6-14 cm in diameter. Occasionally present and damage the rice crop in deltas.



### 2.3. Field mouse, *Mus booduga*

Field mouse, *M. booduga* is distributed throughout India. This tiny animal weights about 10g, with pale sandy body colour in dry areas and dark brown to greyish in other areas. Tail slender, naked, bi-colored shorter than head-body. Nocturnal and fossorial, makes very small circular shallow burrows on dry field bunds and no scoop. Breeds round the year, with litter size- 2-11. In rice ecosystem, though its population outreach the bandicoots, the damage inflicted by them is very minimal and negligible. Trap catch data from rice research station, Maruteru over the years revealed that their population has been reduced drastically over the bandicoots, with the intensified rodent control operations using rodenticide baiting and burrow fumigation with ALP.



## III. Nature of Rodent Damage in Rice

Rodents tend to attack the rice crop from sowing to harvest and cause damage to germinating seeds in the seed bed, growing seedlings in the nursery, tiller damage in the transplanted crop, panicle hoarding in the burrows in ripened crop. Generally lesser bandicoots make a slant cut to the rice tiller at 45° as their chisel incisors move at an oblique angle. Of late, selective feeding by making damage to internal soft growing tissue rather complete slat cutting of the tiller has been noticed in rice variety Bheema (MTU-1140) with hard culm. Hoarding of grains and ripened panicles is the characteristic feature of bandicoots and nearly 8-10 kg of ripened rice panicles or matured gram pods have been recovered many a times, especially during their outbreak periods.

Before transplanting or immediately after transplanting, the rodent incidence was found less (live burrows) though their populations are at higher rates, because of their immigration from the non-cropped areas into the transplanted fields. Meanwhile they are in search of suitable habitat and cause damage to the transplanted seedlings/tillers, which is very scattered in nature. As the crop attains active tillering stage, rodents establish their permanent burrow habitats on field bunds near the crop areas and cause damage to the rice tillers within the restricted home range repeatedly, thus resulting in

damage in isolated patches. Most of the times the response of the farmer is reactive rather than proactive in case of rodent control activities.



In rice, the tiller damage caused by rodents and other pests before maximum tillering stage can be compensated sufficiently by the crop, but not at later stages, due to insufficient time, that results in considerable grain yield reduction (Rangareddy, 1989). Simulation studies on rodent tiller damage carried out at Andhra Pradesh Rice Research Institute, Maruteru at active tillering stage of the crop (i.e. 45 days after transplanting in kharif and 35 days after transplanting in rabi) inflicted significant reduction in the grain yield. Further, significant reduction in grain yield was recorded at and above 4 percent simulated tiller damage during both the seasons. Though the crop showed compensation to the simulated tiller damage at all the levels by producing new tillers, was not satisfactorily contributed to the grain yields (Rangareddy, 1989; Srinivasa Rao and Nanda Kishore, 2010). Therefore, 4% tiller damage by rodents before P.I stage is considered as threshold level for rodents in paddy for both kharif and rabi seasons.

#### IV. Rodent Survey and Surveillance

Regular surveys and surveillance activities provides information about the composition of rodent pest species and their population dynamics. It also helps in diagnostics and planning management strategies in any cropping system. It is most important component of rodent management but most often overlooked. Accurate population census is not possible due to migratory habits, changing species composition, diversified habitats and different body sizes of native rodents, however use of signs, tracks, surplus baiting techniques, burrow counts and trappings are some of the methods generally adopted for population estimation. Live burrow count (LBC) method is commonly recommended for field level estimation of rodent incidence especially for lesser bandicoots, which are solitary in living with characteristic burrow structure. Live burrow or active burrow generally look fresh, marks of rodent, fresh excavated soil and cut parts of various plants etc. may also be there. Since a rodent may use more than one opening for activity – this may give false picture of rodent population. Therefore, all the burrows are plugged in the evening and next day early morning the reopened burrows would reveal almost correct picture of rodent numbers. If we know the mean number of rodents residing in a burrow, a correct population of rodents can be estimated by multiplying this with



number of live burrows. This situation generally arises during breeding season when more rodents live in a burrow, otherwise adult rodents occupy single burrow. Looking at National perspective it is recommended that efforts for periodic monitoring of rodent infestation in crop fields at tehsil levels be made based on the number of active burrows per hectare (25 burrows per hectare: low intensity; 25 to 50 burrows/ha: medium intensity and more than 50 burrows/ha: severe intensity).

## V. Rodent Management Methods in Rice

The aim of rodent control is primarily for damage reduction, but not individual rat killing, there is a necessity of monitoring the situation in different ecosystems through either their damage or through their levels of infestation. The control decision may be taken depending on the monitoring surveys. The majority farmers in these rice growing deltas are tenant that too small and marginal, normally do not adopt any rodent control measures, until the initiation of rodent population. The normal practices followed by farmers include bounty payment, trapping with indigenous bamboo traps, poison bait application, which often includes phorate application. These measures are taken by farmers at individual level thereby covering small patches of the crops grown. Reports on mortality of non-target animals like birds also exist in these districts due to acute poisons and their improper use.

### 5.1. Cultural methods

**5.1.1. Habitat manipulation:** This technique is primarily based on ecological concepts wherein the rodents' habitat is manipulated in such a way that creates stress among native rodent pests. The methods are low cost treatments and involve little modification in crop husbandry practices, like ploughing, puddling, removal of wild vegetation and refuge of previous crops (Jain and Tripathi, 1992) and reduction in bund size (Sharma and Rao, 1989) etc. It helps in migration of pest rodents from crop fields. Moreover, the habitat stress created by these practices enhances the chances of rodents falling prey to predators. Similarly early maturing varieties of rice are more prone to rodent attack (Parshad, 1999). Synchronous sowing / transplanting in larger areas also reduce the rodent damage to a greater extent. Studies carried out at A.P. rice research institute revealed that the narrow and less number of bunds recorded lower rodent infestations over the larger bunds and they suggested to maintain the bund diameter less than 30-40 cm to contain the rodent infestation in rice fields. Further, weed and debris free field bunds recorded 50 % less rodent incidence. Trimming of field bunds before transplanting, immediately after puddling disturbs the rodent burrows on field bunds, thus causes the animals to vacate their habitations and fall prey to natural predators.



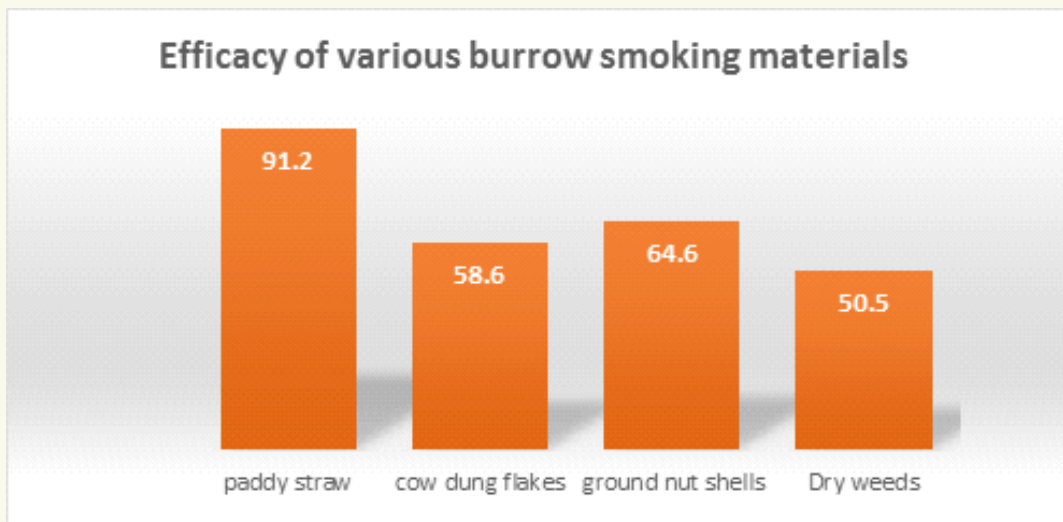
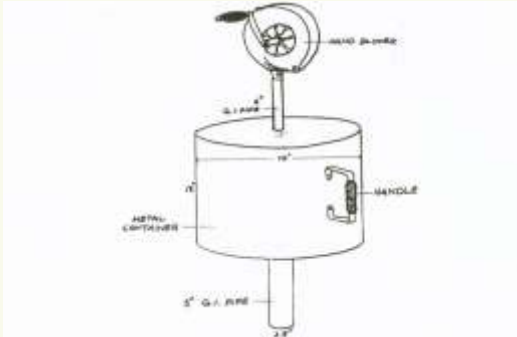
## 5.2. Mechanical and physical methods

Trapping, burrow smoking, mass hunting, burrow digging/destruction, fumigation and poisoning technologies control rodent's infestation satisfactory; however in some times the above technologies may not give satisfactory results because of rat's (rodent's) adaptability, improper application of methodologies, their cognitive abilities and environmental factors.

**5.2.1. Trapping:** Among the various rodent management practices, trapping rodents in fields and premises is a common old practice and it was found quite effective in certain conditions. Two basic types of traps are being in use i.e. the snap or kill trap and the live trap in southern India. Among the snap traps, the Tanjore kitty: a low cost bamboo trap generally used by professional trappers in rice fields in Tamil Nadu (Neelanarayan et al., 1995) and butta: a bamboo snap trap containing a basket for lure placement (Rangareddy, 1994). According to Srinivasa Rao and Nandakishore (2011) butta trap was highly effective in trapping the rodents from rice fields. These two traps are made of local materials viz., palmyra leaves and bamboo sticks, hence they are easily available, eco-friendly, cheaper and easy to operate for trapping rice rodents. In Andhra Pradesh, farmers engage rat trappers for laying butta traps for rodent control, especially after transplanting to tillering stage. Rat trappers charge about Rs. 20-50 per one successful trap, based on demand and even farmers engage them on contract basis by paying 1-2 bags of paddy per acre in a season. Similarly, in NEH region several types of indigenous bamboo made snap traps are laid along the periphery of jhoom fields to trap rodents immigrating from surrounding forests. This practice is often done at crop maturity stage when the rodent's destruction is at its peak, however this eco-friendly method may prove effective if performed in a planned schedule. From rice fields in Godavari delta, more number of rats were trapped during July, August and September in kharif and December, January and February in rabi seasons, mainly due to immigration of the population, when the rice crop was at vegetative stage. The trap catches were minimum during May, which is a lean period (Srinivasa Rao and Nanda Kishore, 2011). Butta traps were advocated @ 20-30/ ac after transplanting the rice to catch the initial migratory population. Though these traps were effective, limits for single animal catch only. The trap catchers were so skilled and they lay the traps in the rodent pathways in their home range keeping paddy grains as a lure in the butta. Some times animal also show its intelligence by making the damage to the butta from other side rather than from the entrance and escapes safely.



**5.2.2. Burrow Smoking:** An eco-friendly mechanical device 'burrow fumigator' has been developed by All India Network Project on Rodent control. The device utilizes farm wastes like paddy straw, ground nut shells and other crop wastes for generating smoke, which is pushed into rodent burrows through a inbuilt blower. Among the various smoking materials, paddy straw was found superior in generating the smoke that cause death in rodents due to asphyxiation (Rangareddy et al., 2005).



Field efficacy in rice fields in Godawari delta, Andhra Pradesh revealed that this device yields over 90% pest mortality, which is at par with chemical fumigant (aluminium phosphide). Efficacy of burrow smoking with paddy straw was studied in comparison with aluminum phosphide (ALP) burrow fumigation for the control burrow dwelling field rodents in sandy and black soils. Among the various natural smoking material tested, paddy straw was found highly effective with 91.20 per cent control of live burrows. Burrow smoking with paddy straw recorded a control success of 90% and 78% in black and sandy soils, respectively. The correspondent success with ALP burrow fumigation was 96% and 88%. The cost of treatment for aluminum phosphide fumigation and burrow smoking were calculated Rs. 4.72/- and Rs. 8.25/- per burrow, respectively. The higher cost of later treatment was due to labor cost and not due to the material cost. Burrow smoking of rodent live burrows is found as an eco-friendly rodent management technique as it does not involve any chemical ingredients (Shakthivel et al. 2021)

Treatment	Burrows in different habitats					
	Sandy soil			Black loam soil		
	No. of burrows treated	No. of burrows re-opened	% control success	No. of burrows treated	No. of burrows re-opened	% control success
Burrow smoking	50	11	78%	50	5	90%
AIP @ 2 pellets/burrow	50	6	88%	50	2	96%
t- value	2.84			1.12		
Non-Significant						

**5.2.3. Burrow Digging and Trapping:** Certain tribal communities in India viz., Mushars and Nats (Bihar); Yenadis (Andhra Pradesh), Irulas and Kuruwas (Tamilnadu) and many other tribal communities in Northeastern hill (NEH) states consume rodents. Farmers of Andhra Pradesh and Tamilnadu employ such tribals for physical elimination of field rodents (Jain and Tripathi, 2000). In many regions the burrows are flooded with water and escaping rats are killed.

The professional rat catchers (Yanadis in Andhra Pradesh) are highly skillful in identification of live burrows by looking at the rodent pathways, their droppings, movement foot marks. The identified live burrows will be smoked mildly to make the animal inactive inside the burrow, later they dug out the burrows physically with crowbars to catch and kill the animals. Farmers in rice growing areas of Andhra Pradesh generally employ these professional rat catchers during the peak times of rodent incidence i.e. tillering to PI stage of the crop. Rat catchers charge Rs. 25-60 per one animal, even they charge Rs. 80/- per one animal catch during peak incidence, when there is increased demand from all the farmers.



### 5.3. Ecological methods

**5.3.1. Trap Barrier System (TBS):** It is a type of physical control of field rodents by putting fences around crops. Lam (1988) reported that erecting plastic fence around the main rice crop and keeping multiple catch traps near the holes made in the fences protects the crop from rodents. This system described as eco-friendly was named as Trap barrier system (TBS). In later years it was improved by limiting the fencing around trap crop sown before the main crop. The trap crop lures the rodents from the surrounding areas and rodents get trapped in large numbers. The TBS+ trap crop provides a halo of protection to neighbouring rice fields (Singleton et al., 1999). The system broadly referred as ecologically sound rodent management technology when applied on community basis (Community trap barrier system or CTBS) and has proved cost effective in some south Asian countries for rice rat management.

This technology is considered to be effective, environmental friendly, and do not trouble the rice crop. For construct TBS requires 1). Live traps (function: to collect rats, made up of metal mesh, possess 25cm(H)X25cm(L) X 50cm(deep) of holes with cone shape entrance, placed on one sides of trap (wonder trap)). 2). Plastic barrier (fence): the plastic fence act as a barrier for rats, during their navigation toward food search/lure crop; fence plastic barrier is a minimum of 60cm above the ground and dug 10cm into ground with bamboo poles inserted at every 1.5 M distance. Plastic fence with 60 cm height bears hole as the entrance to the live traps, and place/locate barrier inside at 20M of distance. Outside the barrier (all 4 sides) make trench and fill with water constantly (moat) and make mud channels (earth mounds partway) for assess rats toward holes of plastic fence then live traps (barrier). 3). Trap crop: is the rice plants planted three weeks earlier from surrounding/ neighboring crop to attract rats into the TBS. Trap crop (lure crop) 100Mx100M (1ha) size advisable per 10 ha required (50MX50M (0.5ha)/10ha also preferable) and this size block require earlier plantation to surrounding is required. Total 16 live traps required for above size TBS at 20m distance (including 4 sides); Additional traps may establish up to 10no depending on rat population and infestation. This method will work for individual (TBS) and campaign mode (CTBS) effectively.

### Precautions & maintenance:

- Multiple-capture traps must be well constructed to minimize trap shyness, especially the cone through which the rats enter
- Traps must be flush (close) with the fence – rats will use any small gap to enter the enclosure or gnaw to enlarge any small holes
- Good access to the trap entrance – construct earth mounds partway across the moat, leading to traps
- Plant the lure crop 2 to 3 weeks before the surrounding crop
- Empty the traps early each morning
- Check the plastic barrier for holes each day and either repair these or install extra traps at the holes
- Keep the moat free of grass (rats can use this to climb over the fence), & fill with appropriate water level
- Cover traps with straw and supply food to keep rats in good condition (the smell of dead rats will discourage other rats from entering traps)



All India Network Project on Vertebrate Pest Management (ICAR), working at ANGRAU, Maruteru has done extensive research on trap barrier system and modified its structure and application procedure to suit local conditions. In TBS, rising of 2-3 week early trap crop that enclosed in a plastic barrier often becomes practically impossible due to non-availability of irrigation water from the canals. Another disadvantage of TBS is its cost of implementation within the constraints of agricultural mechanization, which is increasing in India. The establishment and maintenance of TBS that enclose a trap crop pose operational problems for farmers using tractors and other machinery. If TBS alone has similar effects on rodent management as TBS+TC, simple linear TBS (L-TBS) designs could be as effective as TBS in some situations, which can be more readily implemented as it reduces cost and interferes less with mechanized farming practices. The experiments conducted by AINP on VPM at research station and farmers' fields revealed that the LTBS also showed superior performance more or less equal to regular TBS (Srinivasa Rao and Nanda Kishore 2010; Srinivasa Rao and Anusha, 2018)



Early or timely sown rice nurseries often suffers rodent attack by nibbling the seeds and its sprouts and damage to growing seedlings, thus necessitates repeated sowings by the farmers. Therefore, farmers in this area generally prefer to delay or postpone the sowing of rice nurseries to escape/ avoid the rodent attack. As a result, transplanting of main crop gets delayed and crop harvestings were often coincides with late cyclonic rains and crop loss. TBS will work on the principle that rodents are attracted to the enclosed trap crop which is sown 2-3 weeks earlier to the surrounding crop. By taking this principle, experiments were carried out to find out the efficacy of TBS in protecting the rice nurseries against lesser bandicoots and its halo protection on the following transplanted crop/ main crop in rice research station farms as well as in the farmers' fields during Kharif season in 2017 and 2018.

**Table. Number of rat trapped in TBS erected around rice nurseries**

Season and Year and location	No. of Rats trapped		Sex of <i>B. b</i> trapped		Stage of the animals trapped	
	<i>B. b</i>	Others*	Male	Female	Juveniles	Adults
<b>Kharif 2017</b>						
Research Station	08	02	04	04	02	06
Farmer (L.Koderu)	12	01	07	05	02	10
Farmer (BMoguturu)	07	-	04	03	03	04
<b>Kharif 2018</b>						
Research Station	16	01	14	02	03	11
Farmer (K. Chikkala)	10	-	06	04	04	06
Farmer(Eletipadu)	21	01	17	04	04	17

\* others – snake/ mongoose etc

Source: Rodent Newsletter 1() 2018



The trap catches ranged from 7 to 12 during 2017, it was 10 to 21 during 2018. It shows that the populations were low during 2017 compared to 2018. The predatory snakes and mongoose were also trapped in to the TBS might be during the process of chasing their rodent pray during night time. When the sex of the trapped bandicoots was identified, interestingly most of them are males (52) and few females (22). It can be viewed in supporting to the known fact that the females were attracted to the crop more during PI and flowering, mostly to acquire/ingest plant sap containing its breeding precursors/ stimulating substances, which needs further detailed investigation. Among the trapped individuals, adults comprised more (16-34) compared to juveniles (7-10) during both the years.

**Table. Efficacy of TBS against rodents in rice nurseries**

Treatment	Nursery damage (%)		Live burrows (LBC/ha) in main field in a radius (m) (mean of 2017& 2018)		
	2017	2018	10 m	50 m	100 m
TBS	0.0	0.0	12.4	6.4	10.8
Farmer practice	3.8	8.6	22.6	21.4	18.6
Control	8.4	16.8	23.8	26.4	21.4

*Source: Rodent Newsletter 1(), 2018*

Nursery damage was nil in TBS erected plots or in other words TBS has offered cent per cent protection against field rodents in protecting the rice nurseries. Whereas in other fields recorded with 3.8 to 16.8 per cent nursery damage due to rodents. From the above studies it was established that, TBS is one of the best effective rodent management technology against lesser bandicoots in irrigated rice ecosystem, especially in rodent endemic areas. This technology should be promoted by the government agencies by subsidizing the input costs as it was an eco-friendly technique with no chemical poisons.



## 5.4. Biological methods

**5.4.1. Microbial organisms:** microbes (fungi, bacteria, viruses and protozoans) and macroparasites (helminthes and arthropods) are known to cause diseases to variety of mammalian hosts including rodents, however their potential as bio- control agents has not been realized so far. Bacteria *Salmonella typhimurium* and *S. enteritidis* have been successfully used against rodents in foreign countries but in India, the pathogen was found ineffective against *R. rattus* and *B. bengalensis* yielding only 16 and 18% mortality respectively (Deoras, 1964). A protozoan parasite, *Trypanosoma evansi*, the causal organism of Trypanosomiasis in cattle, has been tried against *R. rattus* and *B. bengalensis* in India and recorded cent per cent mortality after second peak of parasitism (Singla et al., 2003). In fact use of microbes has very little scope for rodent control particularly due to inherent possibility of spread of the diseases to man and livestock.

**5.4.2. Predators:** Several vertebrates, mainly birds and mammals are listed as natural predators of rodents in literature (Deoras, 1964; Prakash and Mathur, 1987, Tripathi et al., 1992; Neelananarayanan, 1997; Chaudhary et al., 2001). However cats in domestic situation and snakes, owls, mongoose and varanids are predominant vertebrates predators of rodents (Rao, 2003). Information on stomach contents and fecal matters of predators indicated that rodents constitute over 75% diet of snakes viz., Cobra and Russel viper (Whitaker and Dattari, 1986) and 61% of spotted owl (Kumar, 1985). In the Cauvery Delta of Tamilnadu, India studies on barn owl as potential bio-control agent revealed a predation rate of 1-6 (Av 1.58) rodents/night. *B. bengalensis* (40%) and *M. musculus* (33%) constituted the major prey items of barn owls (Neelananarayanan, 1997). Such predators need to be introduced and rehabilitated for ecofriendly management of rodents. Establishment of 2-3 owl perches per acre or artificial owl boxes at undisturbed elevations in crop fields is highly recommended to establish and multiply native owl population to keep the rodent pests under check.



**5.4.3. Botanicals:** Some plants products have been found to possess anti rodent properties. Crude cottonseed oil (5%) possesses anti fertility effects on bandicoots (Singla et al., 2008). Derivatives of alkaloids, cyanogenic glucosides etc are likely to disrupt the metabolic processes or even affect the nervous systems of herbivores. These studies do reveal a good scope for such plant/ products in developing non-toxic approach for rodent management and therefore require in-depth study. Gossypol treated baits have also resulted in reduced sperm motility, live sperm count and sperm concentration.

Repellent effect of several botanical extracts were studied in rice fields at rice research station, Maruteru. Among the botanical extracts garlic extract+ castor oil (1:1)- 10% recorded the 42, 37 and 27 per cent reduction in rodent incidence compared to control at 5,10 and 15 DAT. The commercially available botanical based EcodonR recorded superior performance with 65,58 and 42 per cent reduction in live burrows over the control at 5,10 and 15 days after treatment (Sudharani and Narasimha Rao, 2014, Srinivasa Rao and Anusha, 2020)

## 5.5. Chemical methods

Use of rodenticides is the most common, expedient and humane method to control pest rodents and therefore form the basis of present day rodent management strategy in most part of the world. They have greater scope in large-scale control operations, since mixed population of several species are encountered in fields.

**5.5.1. Botanical rodenticides:** The plant origin compounds like, redsquill and strychnine are historical rodenticides. Redsquill, derived from bulbs of *Urginea maritima* was effective against wide range of rodents as scilliroside (a glucoside) and its micronized form was used at 0.05% in baits. In India it has been evaluated against *R. norvegicus*, *R. rattus*, *B. bengalensis* and *T. indica* (Prakash and Mathur, 1987). Botanical baits of *Jatropha*, *Neerium*, *Datura*, *Castor*, *Custard apple* etc tested against lesser bandicoots under laboratory have inhibited the consumption or in other words deterred the feeding. Baits containing *Datura*, *Nerium* and *Jatropha* has caused the significant mortality i.e. nearly 80% at their higher doses of 20% concentration. Though the percent mortalities were significant, the mean mortality times were found higher when compared to existing chemical rodenticides. The mean mortality periods varied between 8.75 to 13.5 days and it was lowest with *Nerium* (8.7 to 9.4 days) among the potent botanicals (Srinivasa Rao and Anusha, 2020)

**5.5.2. Chemical rodenticides:** The rodenticides registered under the Insecticides Act, 1978 broadly belong to two categories based on their ingestion - oral and respiratory. Between oral rodenticides again two types exist - (i) fast acting or acute, which bring mortality within 24 hours and (ii) slow acting or chronic, which bring mortality after 3-5 days based on the toxicant. Among oral toxicants, six rodenticides exist registered under the Act, while only one fumigant can be classified under respiratory poison category. Two rodenticides exist under the acute rodenticides, while four comes under the category of chronic rodenticides.

In India, the following rodenticides are registered for use against rodents:

Acute rodenticides	Chronic rodenticides	Fumigants
1. Barium Carbonate	1. Fumarin	1. Aluminium phosphide
2. Zinc phosphide	2. Warfarin	
	3. Bromadilone	

### 5.5.2.1. Acute rodenticides:

Among acute rodent poisons, only zinc phosphide, barium carbonate and aluminium phosphide are registered by Government of India for common use. Prakash and Mathur (1987) reported that barium carbonate possesses low toxicity with variable efficacy against rodents, is required at very higher requirements in baits (10-20%) and is therefore not in use presently.

Zinc phosphide (Zn<sub>3</sub>P<sub>2</sub>): Zinc phosphide is greyish black, garlic like smelling powder, produced by direct combination on zinc and phosphorus. It is the most commonly used acute rodenticide in the world. In India also it is widely used by the farmers which commonly called by farmers as black powder. Zinc phosphide baits are quite stable in air and non-acidic media & insoluble in water and alcohol, stable when dry, but decomposes gradually in moist air. Acids decompose it quickly leading to the production of lethal gas Phosphine, which is very toxic to mammals. The acute oral toxicity of zinc phosphide to rice lesser bandicoot was 35.0 mg/kg. This poison is widely used against field rat and mouse infestations. Zinc phosphide is recommended at 2-2.5% concentration in cereal baits. It yields around 60% control success. Major limitation in its frequent use is its high toxicity to non-target species and development of bait shyness/poison aversion in the target species after sub-lethal consumption (Prakash and Mathur, 1987). Bait shyness may persist for more than 2-3 months in different rodent species. The persistence of bait shyness was reported as 30 days in *B. bengalensis*, 105 days *B. indica*, 95 days in *M. booduga* and 75 days in *R. rattus* those infest rice crop. Its bait can be prepared by mixing the poison (2-2.5%) in oil smeared cereals viz., wheat, rice, sorghum, pearl millet etc. Because of high toxicity, zinc phosphide is not recommended for commensal situations.

Zinc phosphide will react with water to produce phosphine (PH<sub>3</sub>) and zinc hydroxide (Zn(OH)<sub>2</sub>):  
$$\text{Zn}_3\text{P}_2 + 6\text{H}_2\text{O} \rightarrow 2\text{PH}_3\uparrow + 3\text{Zn}(\text{OH})_2$$

Zinc phosphide when used as bait reacts with water and Hydrochloric Acid (HCl) in the gastrointestinal tract of rodents & to produce Phosphine gas.

### 5.5.2.2. Chronic rodenticides

In chronic rodenticides, only anticoagulants were registered and available for field use in India though several non-anti-coagulant rodenticides (Calciferol, cholecalciferol, bromethalin and Flupropadine) proved their efficacy in several field research experiments conducted in India and elsewhere.

Anti-coagulant rodenticides interfere with blood coagulation process leading to internal bleeding and hemorrhage in the target animals. As per the provisions of Insecticide Act (1968) only four anticoagulants i.e. warfarin, coumatchlor, coumatetralyl and bromadiolone were registered in India (Mohan Rao and Malla Reddy). Warfarin has been withdrawn from the market as most of the pest rodent species has developed resistance after its large scale use. Presently, bromadiolone is the only anticoagulant rodenticide available in India and it has been in use for containing the field rodents.

The efficacy of second generation anti-coagulants i.e. Flocoumafen and Difenacoum were evaluated against lesser bandicoot, *Bandicota bengalensis* under choice and no-choice conditions in the laboratory by AINP on VPM at Maruteru. Both the rodenticides including bromadiolone has recorded 100% mortality in the test animal @0.005% concentration, but with varied time mortality periods of 3.8±0.24 and 4.6±0.25, respectively as against 5.5+0.56 in bromadiolone. In bi-choice laboratory tests, the mean daily intake of plain bait and poison bait was near similar with no significant difference. But, once the animal is ingested with anticoagulant poison bait during the 24 hr of test feeding period in

no-choice condition, later its plain bait consumption was drastically reduced compared to its consumption before the test period. In field studies conducted by the same research station showed that Flocoumafen has offered 71.3 and 62.8 per cent reduction in live burrows and tiller damage of *B. bengalensis* in rice, where as it was 61.9 and 51.7 per cent with difenacoum and 57.2 and 51.1 per cent with bromadiolone during field trials. Flocoumafen found highly effective and significantly superior in containing the live burrow counts and tiller damage caused by *B. bengalensis* in rice (Srinivasa Rao et al. 2018)

more than a decade, particularly in rodent endemic States like Andhra Pradesh. Chances of developing tolerance/ resistance by the lesser bandicoot, *B. bengalensis* against bromadiolone are quite fair, especially in areas of its long time use. Rice growing farmers of Godavari Delta of Andhra Pradesh often complaints in several forums that the bromadiolone is failing in containing the rodent damage in rice. Studies on bromadiolone tolerance in field populations of *B. bengalensis* conducted at AINP on VPM, Maruteru centre revealed that the field populations has showed the signs of tolerance with an increased mean mortality periods upto 15-20 days, but none of the animal survived once fed with bromadiolone bait in the laboratory (Anonymous, 2020). Hence, there is a need for screening of other anticoagulants for their efficacy against predominant pest rodent species and make them available to the famers for field use.

### 5.5.2.3. Fumigants

Aluminium phosphide (AIP): is an inorganic compound used as a wide band gap semiconductor and a fumigant. Aluminium phosphide reacts with water or acids to release phosphine following hydrolysis



ALP is the most common fumigant rodenticide is available in both tablet and pellet forms, however only pellet formulation is recommended for rodent burrow fumigation (Rao, 2003). But, recently the pellet formulations were banned in India by CIBRC, hence only tablets are available for fumigating the rodent burrows. For fumigation, all the existing burrow openings are plugged with wet mud and aluminium phosphide tablet is inserted in the active burrows, which should also be plugged with mud to check the escape of lethal gas. All the nearby burrow openings need to be plugged invariably. The dead rodents are to be collected next day and disposed off. The fumigant is more effective in humid zone and irrigated fields with heavy soil. It is never recommended for residential premises/indoor use. Because of its extreme toxicity to non-targets and absence of an antidote, Government of India has put this chemical under restricted ban.

A new formulation of aluminium phosphide with reduced a.i. (6.0%) and increased weight (12g) with addition of bitterant is available under trade name "Fumirat" exclusively for treating the rodent burrows. This formulation was evaluated at field level by different AINP centres and it was found to have similar potency as that of existing formulation (56% a.i.) against burrowing field rodents. The results of field experiments on efficacy of 6% ALP formulation, conducted during 2007 at rice research station, Maruteru are summarized below

Treatment	Dosage	% rodent control success
AIP (6% a.i.)-12 g. tablet	One tablet per burrow	95.71
AIP (56% a.i.)- 0.6 g pellet	2 pellets per burrow	85.00

In rodent endemic areas or when the rodent problem is quite serious, fumigant like Aluminium phosphide can be used to treat all the residual rodent burrows in the field conditions. The residual burrows are the reopened burrows after closure of the burrow entrances with mud one day prior to the observations. Fumigation should be done under the technical guidance and strict supervision of officials from the State Department of Agriculture.

## VI. Rodenticide Application Techniques

### 6.1. Rodenticide baits:

'Rodents cannot vomit' is the key for the success of baiting technology. The objective of the baiting technology emphasizes that maximum population of rodents get access to the baits prepared in the most preferred medium. Normally two types of options (i) ready to use and (ii) freshly prepared baits are available. In India normally freshly prepared baits are preferred for field rodent control. Based on the behavior and preferences of rodents and cropping system, the poison baits are prepared in cereal (pearl millet/ wheat/ rice/ sorghum etc) loose baits using edible oils (mustard/ ground nut/ sesame/ coconut oils) as adherent and attractant. The recommended dosage for zinc phosphide and bromadiolone, the commercially available rodenticides in India is 2.0 and 0.005 per cent, respectively in baits. For zinc phosphide which is an acute poison, 2-3 days pre-baiting is recommended for acclimatization of field rodents to overcome neophobia and also to reduce chances of bait shyness. For anti-coagulants pre-baiting is not required.

### 6.2. Rodenticide bait preparation:

Proportion of zinc phosphide poison bait:

Broken rice	96 parts
Edible/Cooking oil	2 parts
Zinc phosphide (80% a.i.)	2 parts

Proportion of bromadiolone poison as follows:

Crushed rice	96 parts
Edible/ cooking oil	2 parts
Bromadiolone (0.25% a.i.)	2 parts



### 6.3. Application of rodenticide baits:

Placement of bait is one of the most important aspects for an effective chemical rodent control strategy. It should however, be ascertained that the rodent population consists of adults only who can consume bait material. The bait may be placed either in the burrows or in the bait containers/bait stations.

**6.3.1. Burrow baiting:** Burrow baiting is advisable in field conditions where clear rodent burrows are visible. For this, all the existing burrow openings should invariably be plugged in the evening and next morning re-opened/ active



burrows are treated with pre/poison baits. The treatment of only active burrows saves the poison bait material, labour cost and time. The poison bait is rolled deep inside the active burrows (@ 6-15 g/ burrow) to avoid any secondary hazards. To assess the control success the burrows are plugged again after 3-4 days of treatment with zinc phosphide or 15 days after bromadiolone baiting and the reopened/ live/ active burrows are accounted.

**6.3.2. Baiting through bait stations:** Application of poison baits can be done in bait stations also. Several types of indigenous bait containers have been used in India for keeping the baits. The basic idea of selecting bait containers is that the bait should be easily accessible to the target species only and reduce the hazard to other animals. This will also protect the baits from rain and other weathering. Indigenously procured items like mud channels, hollow bamboo pieces, broken pitchers, coconut husk/shells, scooter tyre pieces, PVC pipes etc. have been evaluated at rice research station and coconut husk and PVC pipe bait stations are found best suited to deliver poison baits in irrigated rice ecosystem.



PVC pipe bait stations made from 3- inch 1.5 feet PVC pipe horizontal piece or constructed in an upside-down T-shape found highly effective in delivering the poison baits to the target animals with nil access to the non-target birds and full protection from weather. These bait stations need to be placed intact aligning the field bunds using bamboo pegs and binding wire. Placement of 10 PVC pipe bait stations on field bunds of one acre of rice field has recorded the maximum bait intake by the bandicoots under medium to high level of incidence in rice. The bait intake was progressively increased with the progress of age of the crop up to maximum tillering stage and decreased gradually thereafter once the crop enters into reproductive phase and it was negligible during lean period i.e. from May to June. The live burrows counts and tiller damage were much lower in treated block compared to control block. Cement make permanent bait stations were also found successful in effective delivery of poison baits in rice (Srinivasa Rao and Nanda Kishore, Green farming) but interferes with frequent field operations. Hence, these can be best advocated in orchards and plantation crops, where field they can be cost effective and cause nil the field disturbances are minimum.

## 6.4. Rodenticide bait application schedule

**Day 1 :** Make a survey in the area to locate rodent burrows on the bunds and no mans lands around the fields. Identify the live rodent burrows, through the presence of soil plugs and faecal pellets.

For using acute rodenticide like zinc phosphide keep pre bait of approximately 20 g. broken grain of staple food with little amount of vegetable oil.

Or

Prepare poison bait of Bromadiolone at 0.005% a.i. in cereal base. Keep the bait approximately 15 g. wrapped in paper packet inside the burrows.

**Day 4 :** Prepare zinc phosphide poison bait at 2.5% using broken grain of staple food with vegetable oil as binding medium.

Keep bait deep in the burrows.

**Day 5 :** Close all rodent burrows.

Locate dead rodents and bury them. Normally most of the rodents die inside the burrows. Hence, mostly dead rodents cannot be seen.

**Day 6 :** Treat the residual burrows with anticoagulant like Bromadiolone based on the situation.

Place 1 piece of Bromadiolone wax block (16.6 g.) or 15-20 g. of loose Bromadiolone bait (0.005% a.i. Bromadiolone mixed in bait material) in packets in all the reopened burrows. With Bromadiolone, rodents die between 3-10 days after the placement of bait material.



## VII. Integrated Rodent Pest Management

Integrated Pest Management (IPM) is a bio-ecological system which and is therefore dynamic one. The concept of IPM has been devised and applied on insect, diseases and to some extent on weeds so far, however applying the same principles for rodent pests has several limitations. The rodent

management today is mainly reactive one, i.e., when the rodent problem is observed. Simply knowing the control methods does not qualify for effective management of rodents, unless eco-biology and behavior of the enemy (pest) is well known. Since rodents are highly evolved mammals and its long association with the wisest mammal i.e. man, has made them wiser by learning various tactics to avoid many harmful activities performed by man. Trap avoidance, bait shyness/aversion to acute poisons, resistance/cross resistance to anticoagulants are only few examples of rodents' complex behaviour, which very often questions the man's endeavors' for their control. Therefore an IPM approach based on sound eco-biology and ethology of pest species vis-à-vis population reduction technologies having economic viability and sociological acceptance needs to be evolved.

Although several methods of rodent control has been discussed in preceding pages, but no single method can prove its worth if applied in isolation. Despite the need of the hour, the real IPM for rodent pests still not happening, because of several in built constraints due to complex biology and behavior of the pest rodents. Present day rodent control technology mainly depends on the use of rodenticides, which no doubt yields quick results and farmers are also satisfied by seeing the dead rodents or immediate reduction in damage. This success with rodenticidal baiting is a short lived and soon the survivors multiply or other rodents immigrate from surrounding areas making the whole exercise of rodent control a futile one. However rodenticides are going to stay till better options are made available, but based on the present day knowledge on Indian rodents these can be used judiciously and may be integrated with other methods viz., habitat manipulations, trapping etc so that use of toxic chemicals are at least minimized. Field experiments were carried out to study the efficacy of various rodent management techniques applied in a module Vs their solo application. Integration of rodent management techniques in Module-1 (trapping- bromadiolone poison baiting – burrow smoking) and Module-2 (ZNP poison baiting- bromadiolone poison baiting-ALP burrow application) found promising with significantly lowered rodent incidence and crop damage (Srinivasa Rao, 2021).

## VIII. Future Thrust and Conclusion

Knowledge generated on population dynamics, breeding-biology, behavior of pest rodents one may plan the rodenticidal treatments in fields. Jain and Tripathi (2000) opined that since most of the field rodents show lean breeding periods during summers (May-June), a community based anti-rodent campaign may be launched during this period. It provides greater rodent control success because (i) acceptance of poison bait is very high in absence of green food (ii) ingestion of poison bait is higher as majority population are in adult stage (being a lean breeding period) and (iii) farmers are relatively free to undertake campaign which reduces the cost of operation also. This treatment takes care of kharif (monsoon) crops. Similar operation may be carried out in November – December months for rabi (winter) crops. Parshad (1999) terms these treatments as prophylactic. During crop growth stages, poison baits are less acceptable due to stiff competition with green food and at this stage trapping or rat catchers may be employed. Indian farmers, mainly due to poor awareness avoid any control actions when the crops are not in the fields. Therefore curative actions are to be taken. During peak breeding periods, instead of poison baiting, burrow fumigation with chemical or smoking of burrows with fumigator may be more effective as it eliminates adults, sub adults, juveniles etc. Late evening application of bait is ideal for treating the burrows of *B. bengalensis*, which helps rodents to get fresh baits.

In the era of IPM the present rodenticide based technologies needs immediate refinements, because dependence on toxic chemicals has several limitations in view of environmental, economic and social considerations. What is needed in chemical rodent control tool is relatively safe rodenticides, like

anticoagulants or vitamin D3 based rodenticides; scheduling of treatments according to bio ecology and behaviour of pest rodents vis a vis vulnerability of crop stage and suitable bait delivery techniques. Addition of a bitterant, denatonium benzoate (10 ppm) in bromadiolone baits makes it safe to non-targets, especially humans without affecting its efficacy. The problem with the anticoagulants is development of resistance in pests. There is an urgent need to have more number of anti-coagulants in India to avoid dependence on a single chemical i.e., bromadiolone. As far as bait delivery systems are concerned paper packeted baiting, bait stations made of coconut husk, banana sheath, PVC pipes or bamboo stems have shown good promise in many parts of the country and therefore may be utilized on a large scale.

Pest rodents often pose serious threat to rice cultivation, especially in rodent endemic deltaic paddies. With changes in agro climatic conditions and cropping patterns rodents are showing shifts in their distribution and abundance (Parshad, 1999). Although effective options for their management are available in the country, the rodents continue to be a serious threat to food and health security. One of the most important constraints is the lack of community participation in rodent management actions. Most of the farmers show general neglect towards the problem due to poor awareness, small land holdings, low education and economic status. Many a times failures of rodent control activities due to adoption of wrong methods of bait preparation and application also discourages the farmers. The social engineering activity on rodent control initiated by All India Network Project on Rodent Control yields over 60% success in the adopted villages (Mathur, 1992). Government of India has launched a National Plan on Rodent Pest management with major objective of awareness creation; capacity building and rodent control campaigns (Rao and Rao 2018).

The Global climate change as evident from increase in temperatures and changing rain fall patterns are likely to accentuate the rodent problem further as these tiny vertebrates would successfully adapt to any such changes. Intensive cropping and extension of rice cultivation to new areas by providing assured irrigation through new irrigation projects will certainly facilitate the bandicoots ingress and their persistence, thus the challenges from pest rodents are manifold. Chemical control methods using rodenticides needs to be refined in view of their efficacy, safety to non-targets and cost effectiveness. The other methods may be integrated as a package of technology. However, major emphasis is required on use of non-lethal approaches, like trap barriers, repellents and biological control with predators, pathogens and anti-fertility agents. The mechanism for effective transfer of rodent management technologies to end users too needs strengthening by exploring various mass media tools for education, training and field demonstrations of the technologies.

## References:

Rangareddy, A. 1989. Evaluation of the reduction in the grain yield by simulated rat damage. Annual Progress Report of AICRP on Rodent Control 1988-89, Andhra Pradesh Agricultural University, Maruteru.

Rangareddy, A. 1994. Rodent management in cereal crops with reference to rice. Paper presented to the Apex Level Rodent Control Training. ICAR, NEH Complex, Barapani, Shillong, 24-26 October, 1994, pp 86-92.

Sridhara, S. 1992. Rice In: Rodents in Indian Agriculture., Vol 1 (Eds.) Ishwar Prakash and P. K. Ghosh, Scientific Publishers, Jhondpur, pp.211-230.

Nanda Kishore. M and N. Srinivasa Rao. 2007. Sustained baiting-a strategy for improving the efficacy of rodent control in rice. Pest mgmt. and Economic zoology 15(2): 171-176.

Nanda Kishore, M and N. Srinivasa Rao. 2009. Social engineering on rodent control through participatory adoptive research in Andhra Pradesh. Green Farming 2 (5): 206-307.

Srinivasa Rao, N and M. Nanda Kishore. 2009. Seasonal changes in the population size and reproduction of *B. bengalensis* in rice-rice-pulse ecosystem in A.P. Indian Journal of Plant Protection 37(1&2): 59-63.

Srinivasa Rao, N and M. Nanda Kishore. 2010. Evaluation of Trap Barrier system for the management of lesser bandicoot rat, *B. bengalensis* in irrigated rice. Indian Journal of Plant Protection 38 (2): 193-196.

Nanda Kishore, M and N. Srinivasa Rao. 2011. Threshold levels for rodent damage through simulation in paddy. Journal of Applied Zoological Research 21(2): 33-35.

Srinivasa Rao, N and M. Nanda Kishore. 2013. Baiting through PVC pipe bait stations –A low cost baiting technique for rodent control in rice. Annals of Plant Protection Sciences 21 (1): 167-171.

Srinivasa Rao, N and M. N. Kishore. 2014. Evaluation of indigenous snap types for trapping rodents in paddy fields of Godavari delta in Andhra Pradesh. Indian Journal of Plant Protection 42 (1): 64-67.

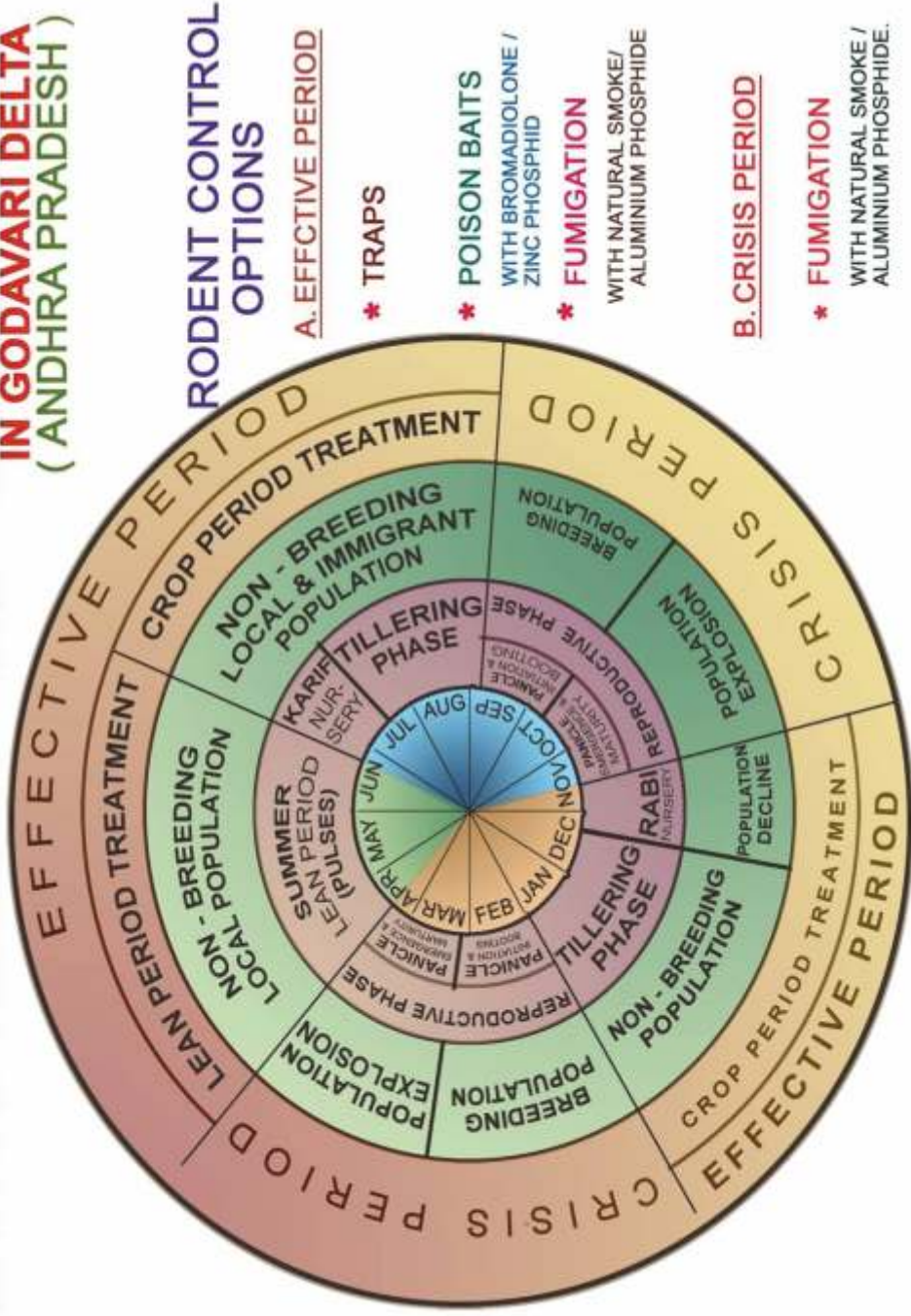
Srinivasa Rao, N and B. Anusha. 2018. Rodent pest scenario and impact of rainfall on incidence and multiplication of *B. bengalensis* in irrigated rice ecosystem of Godvari delta of Andhra Pradesh. Rodent News letter 42(1-4): 4-7

Srinivasa Rao N and B. Anusha. 2018. Trap barrier system: an effective technique for protecting the rice nurseries against *B. bengalensis* in rodent endemic areas. Rodent News letter 42(1-4): 10-12

Srinivasa Rao N, Anusha B., Narsimha Rao Ch. V and Tripathi R.S. 2019. Evaluation of Flocoumafen and Difenacoum against lesser bandicoot rat, *Bandicota bengalensis* (Gray) in rice, Journal of Entomology and Zoology studies 7(3): 907-910



# SEASONAL CALENDER FOR RODENT MANAGEMENT IN RICE IN GODAVARI DELTA (ANDHRA PRADESH)



## RODENT CONTROL OPTIONS

### A. EFFECTIVE PERIOD

- \* TRAPS
- \* POISON BAITS  
WITH BROMADIOLONE / ZINC PHOSPHID
- \* FUMIGATION  
WITH NATURAL SMOKE / ALUMINIUM PHOSPHIDE

### B. CRISIS PERIOD

- \* FUMIGATION  
WITH NATURAL SMOKE / ALUMINIUM PHOSPHIDE.

