Rodent pests of coconut and their management

A

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CERTIFICATE- I

This is to certify that the thesis entitled **"Rodent pests of coconut and their management"** submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE IN AGRICULTURE (ENTOMOLOGY)** to the Orissa University of Agriculture and Technology is a faithful record of bona fide and original research work carried out by **Pooja Konhar** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

Sahoo
03.7.2017
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CHAIRMAN

ADVISORYCOMMITTEE

CERTIFICATE –II

This is to certify that the thesis entitled **"Rodent pests of coconut and their management"** submitted by **Pooja Konhar** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (ENTOMOLOGY)** has been approved by the students' advisory committee and the external examiner.

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ABSTRACT

Rodents are serious non-insect pests in some coastal areas of Odisha damaging green tender nuts of coconut palms. Roof rat, *Rattus rattus* L. is the most dangerous rodent species that cause a hole near the perianth region of tender nuts and drink the water content. The damaged nut becomes weak and falls down to the base of the palm. A study entitled "**Rodent pests of coconut and their management**" was undertaken to know the per cent rodent infestation and nut damage, species composition of rodents, efficiency of various management practices against rodent damage and cost benefit analysis of various treatments in coconut plantations. A survey was conducted in some areas of Coastal Odisha during the year 2015-2016 to know the per cent rodent infested palms and nut damage. The results revealed that the per cent rodent infestation and nut damage varied from 2.63% to 50.7% and 1.28% to 26.02% respectively. Biraramchandrapur area of Puri district recorded highest per cent rodent infested palms (50.70%) and nut damage (26.02%). Monitoring on rodent abundance in coconut plantations during the year 2015-2016 revealed highest trapping index in the month of January, 2016 *i.e.* 25.57%. Biraramchandrapur village recorded highest per cent trapping index (12.41%) followed by Oterkera (9.81%) and Resinga (8.33%). Studies also revealed *R. rattus* to be the predominant species (89.57%) in coconut orchards of Coastal Odisha. Field evaluation of various management practices against rodent damage (Crown baiting with bromadiolone (0.005%) wax blocks, trunk banding with polyester slippery sheet, trunk banding with G.I sheet, trunk banding with polyethylene sheet and untreated check) revealed that all the treatments gave excellent control of nut fall during the 10 months of study. The highest per cent reduction in nut fall over pre-treatment count as well as untreated check *i.e.* 99.86% and 99.88% was recorded in trunk banding with G.I sheet respectively followed by polyester slippery sheet *i.e.* 99.79% and 99.82% respectively. The incremental cost: benefit ratio was found to be highest in case of crown baiting with bromadiolone (0.005%) wax blocks (1: 5.12) followed by trunk banding with polyester slippery sheet (1: 2.07). The overall impact assessment of farmers in adoption of social engineering activities for rodent control during 2015-2016 and 2016-2017 showed that adoption of crown baiting with bromadiolone (0.005%) wax blocks increased from 0% to 56.4% after training. Among the various management practices, trunk banding with G.I. sheet proved best in controlling nut damage, however this cannot be advised to farmers because of low cost: benefit ratio (1: 1.63). Crown baiting with bromadiolone (0.005%) gave 94.29% reduction in nut fall over untreated check and maximum benefit in terms of profit. Thus farmers can be advised to adopt this practice for better management of rodent damage as well as for deriving high profit. Our training on various social engineering activities against rodent control was adopted by maximum farmers giving a positive impact. However further training on rodent damage and their management is required for generating awareness.

CHAPTER- I

INTRODUCTION

INTRODUCTION

The coconut palm (*Cocus nucifera* L.) considered as the "King of palms" and "Nature's super market" is essentially a tree of life for millions of small and marginal farmers. It is the most useful palm in the world. Every part of the tree is useful to human life for some purpose or the other. Hence, the coconut palm is endearingly called 'Kalpavriksha' meaning the tree of heaven.

Apart from the importance of copra and coconut oil which is widely used in the manufacture of soaps, hair oil, cosmetics and other industrial products, its husk is a source of fibre which supports a sizable coir industry. The tender nut supplies coconut water, a popular thirst quencher of health and hygienic value. Virgin coconut oil (VCO), extracted from fresh coconut kernel without any chemical processes is abundant in vitamins, minerals and anti-oxidants, thus making it the 'mother of all oils'.

India is the third largest producer of coconut in the world after Indonesia (1^{st}) and Philippines (2^{nd}). The area under coconut production in India during the year 2015-16 was reported to be 2088.47 thousand ha with an annual production of 22167.45 million nuts and productivity of 10614 nuts per ha. The four southern states viz., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh together account for 90 percent of the total area and production of coconut and there is high variability in productivity owing to production system. The farmers of these states are destined to flourish or perish depending on the fortunes of coconut industry. Other major traditional coconut growing areas include West Bengal, Odisha, Goa, Puducherry, Maharashtra and the island territories of Lakshadweep and Andaman and Nicobar. According to Coconut Development Board, GOI (2015-16), Odisha contributes in production of 328.38 million nuts from area of 50.91 thousand ha with a productivity of 6451 nuts per ha.

The crop is attacked by both insect pests and non-insect pests. Among the non-insect pests, the rodents are considered to be the most important pests that cause huge damage to the tender nuts. Rodents are highly adaptable mammals belonging to the order Rodentia. The taxonomic name of the order is derived from the Latin word '*rodere*', meaning to gnaw or chew. Rodents are omnivorous, having highly

developed sense of smell, taste and hearing. The principal identifying feature of a rodent is that one pair of incisors above and below are greatly enlarged and used for gnawing. They are serious pests of agricultural and stored food. They cause direct damage to crops/commodities by gnawing and feeding and also indirect damage by spoilage, contamination and hoarding during pre and post harvest stages. Globally 1750 species of rodent have been reported, which represents about 40 per cent of the total mammalian species. About 115 species occur in India and of these, 18 species are pest (Parshad *et al.*, 2007). In India about ten species of rodents are found to co-exist in coconut and cocoa cropping systems. Among them, the runner rat, *Rattus rattus* L. and the striped squirrels, *Funambulus* spp. are the most important ones.

The extent of rat damage to tender coconut varies from 8.7 per cent in certain parts of Andhra Pradesh to 50 per cent in Lakshadweep islands where close planting is practised (Prakash and Ghosh, 1992). Thus various approaches are needed to be followed for effective management of rodents.

Though various measures for rodent control like trapping, banding of tree trunks, use of rodenticides and repellants are available, the major problems in their implementation are general neglect, a lack of awareness of economic losses, small land holdings which make rodent control campaigns difficult to organize over large areas, the low education and economic level of farmers and discouragement due to the frequent failure of rodent control operations as a result of the adoption of the wrong procedures of bait formulation and application (Malhi 1998). Moreover, when compared to the considerable trained manpower and facilities provided for the transfer of other crop production and protection technologies to the farmers, the transfer of rodent control technologies continues to be neglected (Parshad 1992). Often the farmers consider rodents as minor or unmanageable pests and this perception contributes to their lack of interest and motivation to carry out effective rodent control. In coconut plantations, the tall nature of palm, the nocturnal and neophobic behaviour of rodents make their control further difficult.

Thus considering the heavy yield loss in respect of quality and quantity of copra and tender nuts and efficacy and adoption of rodent management practices by farmers, few studies were undertaken. Surveys and experiments were conducted in some heavily affected areas of Puri district to have a brief idea regarding the extent of

damage by rodents, species composition and trapping index in coconut orchards during 2015-2016. As a part of management, trial was carried out to know the efficacy of some management practices at Biraramchandrapur village, Sakhigopal, Puri during 2016-17, which may give an idea for tackling rodent menace. An overall impact assessment was also conducted on adoption of various social engineering activities against rodent control by the farmers both in field and at home. This analysis gave an idea about rodent control from farmer's perspective.

With this backdrop, the present study on "Rodent pests of coconut and their management" was undertaken to achieve the following objectives:

1. To assess the total damage caused by rodents in various coconut orchards of Coastal Odisha.
2. To monitor the rodent pest abundance in coconut plantations.
3. To study the efficacy of different management practices against rodent damage in prevailing coconut plantation.
4. To analyze the cost-benefit ratio of various rodent management practices.

CHAPTER- II

REVIEW OF LITERATURE

2.2 Extent of damage caused by rodents in coconut plantations

In 1982, Rao and Subiah reported that in Andhra Pradesh the damage to tender nuts due to *R. rattus* was about 14.7 per cent. Advani had also recorded rodent damage at a level of 28.5 per cent in West coast variety of the coconut in Western Ghat biome of South India.

Guruprasad and Srihari (1983) found out that in Karnataka the root damage in coconut plantations due to *B. benghalensis* was about 6.8–8.0 per cent.

Advani (1984) concluded that in Lakshadweep islands the damage to tender nuts due to *R. rattus* was about 4.5-55.0 per cent.

Advani (1985) recorded that the damage to tender nuts due to *R. r. wroughtoni* ranged from 21-28.5 per cent in Kerala. He also reported that in Andaman Islands the damage to tender nuts due to *R. r. andamanensis* was about 32.0 per cent.

Shamsuddin and Abdulla Kaya (1985) observed that *R. rattus* makes a single hole on developing and tender coconuts near its point of attachment and feed on the pulp and the damaged nuts fall to the ground.

Sarkar (1986) found out that in Tripura the damage to nuts due to *Sciurus carolinensis* Gmelin and *Sciurus vulgaris* L. was about 15 per cent.

Chakravarthy (1993) found out that in Karnataka the damage to tender nuts due to *F. palmarum* was about 12.0-15.0 per cent.

According to Kapadia (1995) the rats may gnaw through the collar into the crown and kill young plants.

2.3 Efficacy of various management practices against rodent damage in coconut plantation

Parshad (1999) grouped the available rodent control options into two basic approaches viz. lethal or reductional and non-lethal or preventive. The lethal approach, particularly the use of rodenticides and trapping, which provides an immediate solution to the problem, is often considered the most practical, economical and effective method of combating rodents while non-lethal or preventive measures

involving environmental, cultural and biological methods, which may produce a more lasting effect, are seldom adopted.

2.3.1 Lethal Approach:

Shah and Subiah (1978) reported that in Lakshadweep islands the villagers organized 'yeli nayatu' which means rat hunts with participation of the entire community for controlling *R. rattus* in coconut plantations. During the hunt, the climbers climbed coconut trees and after cleaning their crowns they continuously shook them, as a result the rats ran helter skelter and on to the ground below the trees to be killed by another group of people. These hunts have been an annual event in the past killing about 3000– 4000 rats every year on the island.

Sridhara and Srihari (1979) observed that fumigation of burrows with aluminium phosphide was generally effective in damp soils but its importance was limited by toxicity hazards, cost of application and low efficacy against species like *B. bengalensis* which plugged the tunnels of their burrows.

Rana (1982) stated about a trap with foldable iron sheet boxes with a spring loaded shutter commonly called as Sherman traps. This is a single catch trap.

Arora et al. (1982) observed that feeding poison baits containing sub-acute rodenticides like 0.1% calciferol, 0.1% calciferol plus, 0.025% warfarin for 1–2 days caused 100% mortality of *R. rattus*. Most of the rats died after between 3 and 5 days of treatment.

Rao et al. (1984) studied the efficacy of freshly prepared wax cakes of bromadiolone applied as two-time crown baiting against *R. rattus*. The study revealed 100 per cent control of the species.

Parshad (1986) studied the mortality rate in *R. rattus*, *B. bengalensis* and *Tatera indica* Hardwicke using second generation anticoagulant rodenticides. The results revealed that 80–100% mortality occured after ingestion of 0.005% brodifacoum and flocoumafen baits equivalent to just 10–20 per cent of the daily food intake and with 2–3 hours of exposure to the poison baits. Bromadiolone was found to be less toxic and rats needed to eat more bait for a longer period, usually for 24–48 hours for complete mortality.

Advani (1986) studied the efficacy of ready to use wax cakes of both brodifacoum and bromadiolone against *R. rattus* in coconut orchards. He revealed that application of the above mentioned as one time crown baiting gave 73.5 per cent and 75.5 per cent control of the rats respectively.

Prakash and Mathur (1987) reported that the *urang* or arrow trap and the break-back spring loaded snap traps with wooden or jawed iron base have also been used traditionally. Among these the break-back snap trap is most popular.

Parshad et al. (1987) observed that rat families consisting of the mother and 4–10 immature individuals of *R. rattus* were caught in one trap as the species normally lived in social groups and trapping of one individual facilitated that of others in the group. The population pressure of *R. rattus* affects its trapping as trapping is more successful in heavily infested areas where as a few scattered individuals are difficult to trap.

Fitzwater and Prakash (1989) stated that trapping rodents in fields and premises was a common old practice. Two basic types of traps were being used, the snap or kill trap and the live trap.

Sheikher and Jain (1992) studied about multi-catch wonder traps of different sizes and shapes. Pre-baiting the rats in wonder traps for 2–3 days by keeping its door off reduced the effects of neophobic reaction on trapping.

Srihari and Chakravarthy (1992) stated about a wooden snap trap, a locally fabricated trap using timber splinters to be used traditionally.

Prakash and Mathur (1992) mentioned about various acute rodenticides whose toxicity and efficacy had been tested against Indian rodents. Those were zinc phosphide, aluminium phosphide, barium carbonate, arsenic trioxide, strychnine alkaloid, thallium sulphate, alphanapthyl thiourea (ANTU), norbormide, scillirocide (red squill); sodium fluroacetate, vacor (RH-787) and a gophacide. Apart from zinc phosphide, aluminium phosphide and barium carbonate, none of those were commercially used in India because of toxicity and efficacy problems.

Parshad (1992) stated that among the acute rodenticides, zinc phosphide was most commonly used in South Asia and formed the basis of 80–90% of rodent control

operations, particularly in agricultural situations. This is a broadspectrum rodenticide with LD_{50} ranging from 25 to 40 mg per kg in different species of Indian rodents. It can easily be used in different bait formulations generally at 2% concentration in cereal bait; it rapidly detoxifies in carcasses and baits and thus is relatively safe in use, and it is economical. However the major problems with the use of zinc phosphide include its antidotable character, quality problems and bait aversion among sub-lethally poisoned rodents.

Saini and Parshad (1992) observed that feeding poison baits containing 0.075% cholecalciferol for 1–2 days caused 100% mortality of *R. rattus*. After ingesting lethal amounts of cholecalciferol in 1–2 days of feeding, the rats lose appetite and stop feeding. The advantages of this 'stop feed' action caused by a lethal dose is that the rats do not consume excessive overdoses thus reducing bait requirements and the risk of secondary poisoning Moreover, vitamin D compounds pose less toxicity hazards to non-target animals and their accidental poisoning is symptomatic with cortisone and sodium sulphate.

Mathur *et al.* (1992) studied about several first generation anticoagulants like warfarin, fumarin, coumatetralyl, diphacinone and chlorophacinone are effective against most of the species of Indian rodents. Among these are warfarin and fumarin (Ratafin) which are generally used at 0.025% concentration in cereal baits or sometimes as ready-to-use wax bound cakes as of fumarin (Ratobar). These have long been available in India but have not gained popular acceptance for rodent control because they become effective only after several ingestions of small doses over a number of days, ranging 4–28 in different species.

Arora *et al.* (1994) tested bromadiolone, along with other second generation anticoagulants viz. Brodifacoum, Flocoumafen, Difenacoum etc., against rodents in both laboratory and field conditions in India. Compared to first-generation anticoagulant rodenticides, the second-generation were more toxic and effective and thus were used at low doses at 0.005% concentration in the bait, and 0.0025% in case of difethiolone, and are generally effective after a single dose or day's ingestion and thus require a shorter feeding period and less bait.

Greaves (1994) reported that the second generation anticoagulants rodenticides were also effective against rodents resistant to first-generation anticoagulant rodenticides.

Malhi and Parshad (1994) studied the bait acceptance timing of rodents in orchards and stated that during the lean period, the rodents easily accept the poison baits in their burrows as food and shelter are scarce in crop lands.

Neelanarayanan *et al.* (1994) stated about different types of traps for live trapping of rodents, which also included the primitive type pit fall or pot trap.

Parshad and Malhi (1995) reported that burrow application of 2% zinc phosphide bait may result in about 80% rodent control.

Bruggers *et al.* (1995) analysed commercially available zinc phosphide from Bangladesh and showed that only 2 out of 23 samples contained 80% of the active ingredient while 14 had 15% to non-detectable zinc phosphide content. Such a lack of quality control not only discourages farmers from adopting rodent control with zinc phosphide but its use complicates rodent management as the sub-lethally poisoned rodents tend to develop poison bait aversion.

Parshad and Kochar (1995) reported that sub-lethally poisoned rats, in contrast to acute rodenticides, ate sufficient poison bait for a complete kill as they did not develop an aversion to it.

Rangareddy (1995) studied the efficacy of brodifacoum and bromadiolone (freshly prepared cereal bait) against *R. r. wroughtoni* in coconut orchards. Bromadiolone was applied as two-time crown baiting. The study revealed 100 per cent control of the species in both cases.

Neelanarayanan *et al.* (1995) stated that among the Tanjore Bow trap, a low cost bamboo trap generally used by professional trappers in rice fields have been used traditionally.

According to AINP Annual Report (2013-14 and 2014-15) the laboratory trials indicated that for capturing medium sized rats *(R. rattus)*, wonder traps proved superior (89.20%) followed by snap traps (81.74%), modified snap trap (80.77%), box trap (67.94%).

2.3.2 Non-Lethal Approach:

Guruprasad & Srihari (1978) observed that banding the trunk of coconut trees with metallic sheet prevented *R. rattus* from climbing to the crown to get access to the coconuts. About 7.5% coconut trees were infested with rats in an area where the tree trunks were banded compared to 25% of trees which were not banded.

Parshad et al. (1989) reported that the three rodent species, *B. bengalensis*, *Mus musculus* L. and *R. rattus* species breed throughout the year and maintain large populations and their physical abilities allow them to disperse quickly. Different techniques, such as barriers, electric fences, repellents and rat proofing, can be used to prevent the entry of rodents, denying them access to food in agricultural fields and during post-harvest storage.

Rana *et al.* (1994) observed that a reduction in bund thickness and height discouraged bandicoots from burrowing there. Ring weeding and cleaning prevented the rodents to establish their habitat. Crown cleaning of coconut trees drove away *R. rattus*.

Jain *et al* (1993) reported that digging and smoking burrows by burning cow dung cake or rice straw on an opening forced the rodents to leave their habitat.

2.4 Cost: Benefit Ratio Analysis

Rubio (1980) analysed the benefit: cost ratio for trunk banding with G.I sheet. He estimated a benefit: cost ratio of 15:1 on trunk banding based management practices in 10 years experiment.

Reindinger and Libay (1980) estimated that the benefit: cost ratio for crown baiting as a whole ranged from 7.3: 1 to 41.3: 1. Similarly Hoque (1983) also estimated the benefit: cost ratio of 8.8: 1 and 24.4: 1 for coconut and coconut-pineapple intercrop respectively.

CHAPTER- III

MATERIALS AND METHODS

MATERIALS AND METHODS

The materials used and methodology adopted for achieving various objectives in the present study are mentioned here under.

3.1 Survey on extent of damage by rodents in various coconut orchards of coastal odisha.

Survey was conducted in different areas of Coastal Odisha during the year, 2015-2016 to know the rodent infestation and nut damage on per cent basis. Rodent Infestation was calculated using the following formula:

$$\textbf{Rodent Infestation (RI \%)} = \frac{\text{No. of trees with fallen nuts}}{\text{Total no. of trees}} \times 100$$

For assessment of nut damage (%), 10 rodent infested trees were identified in each block. The total number of damaged as well as healthy nuts was recorded. The nut damage (%) was calculated using following formula:

$$\textbf{Nut Damage (\%)} = \frac{\text{Total no of damaged nuts}}{\text{Total no nuts (Healthy \& Damaged)}} \times \text{RI}$$

Fig. 1 Inspection of nut damage

Fig. 2 Survey of rodent infested palms

Fig. 3 Rodent damaged nuts

Fig. 4 Damaged nuts fallen at the base of the palm

3.2. Monitoring rodent pest abundance in coconut plantations

Monitoring of rodent species through monthly trappings was carried out in coconut orchards of Biraramchandrapur, Resinga and Oterkera of Puri district during the year, 2015-16, to know the species composition and trapping index in per cent basis.

3.2.1 Estimation of Trapping Index

For estimation of trapping index, single catch Sherman traps were used. During evening hour twenty traps provided with fried snacks as lure were placed at different spots of the orchard. The traps were collected in the morning hour and number of trapped rodents was noted down. The traps were then washed properly with water and sun dried. This process was repeated consecutively for three evenings. The trapping index was calculated using following formula:

$$\textbf{Trapping Index (TI \%)} = \frac{\text{Number of trapped rodents}}{\text{Total no. of traps}} \times 100$$

3.2.2 Estimation of species composition

The number of rodent species trapped in single catch Sherman traps per day were noted down and identified properly. The species composition (%) was estimated by following formula:

$$\textbf{Species Composition (\%)} = \frac{\text{Total number of a particular rodent species trapped}}{\text{Total number of rodents trapped}} \times 100$$

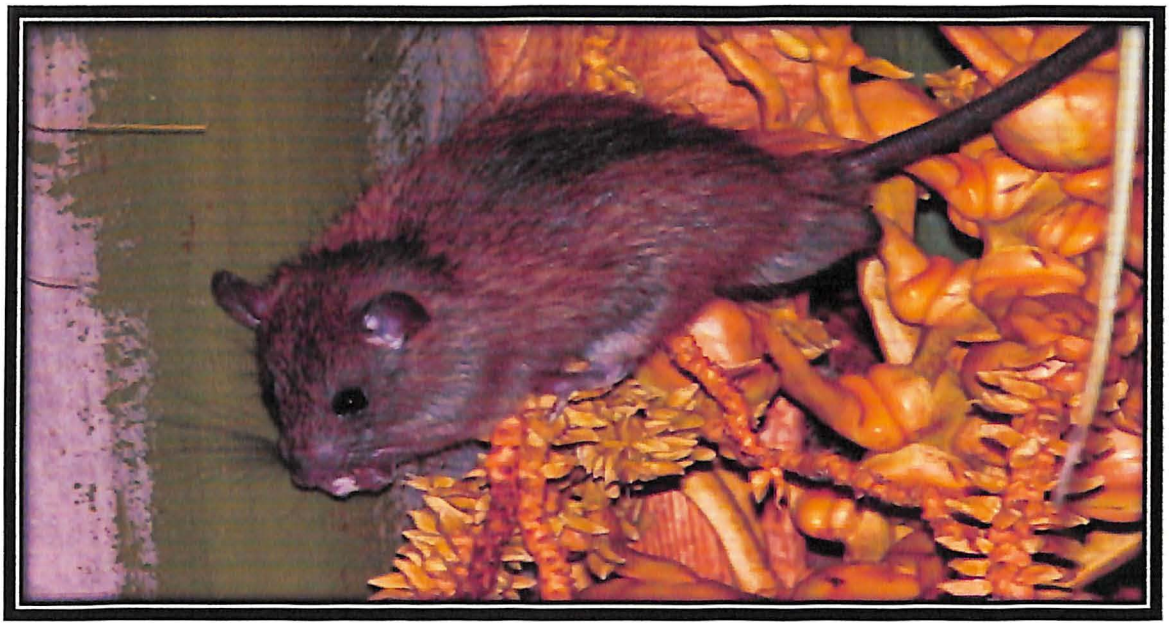


Fig. 5 Roof rat, *Rattus rattus* L.

Fig.6 Lesser Bandicoot, *Bandicota benghalensis* Gray

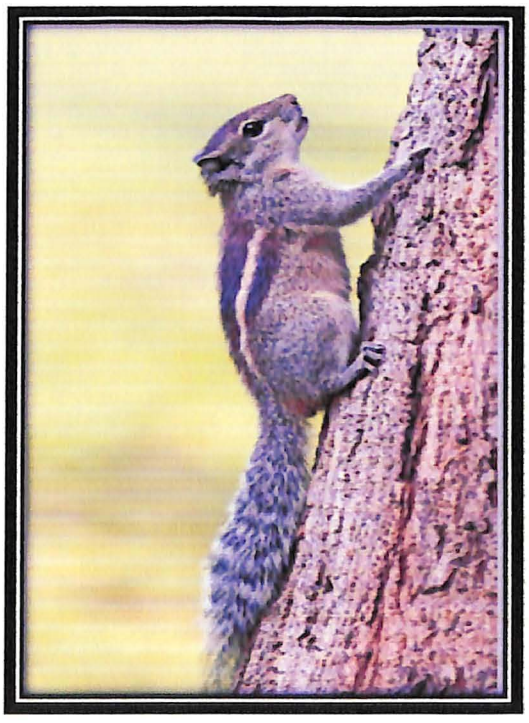


Fig.7 Three stripped palm Squirrel, *Funambulus palmarum* L.

Fig. 8 Placement of traps in coconut orchard

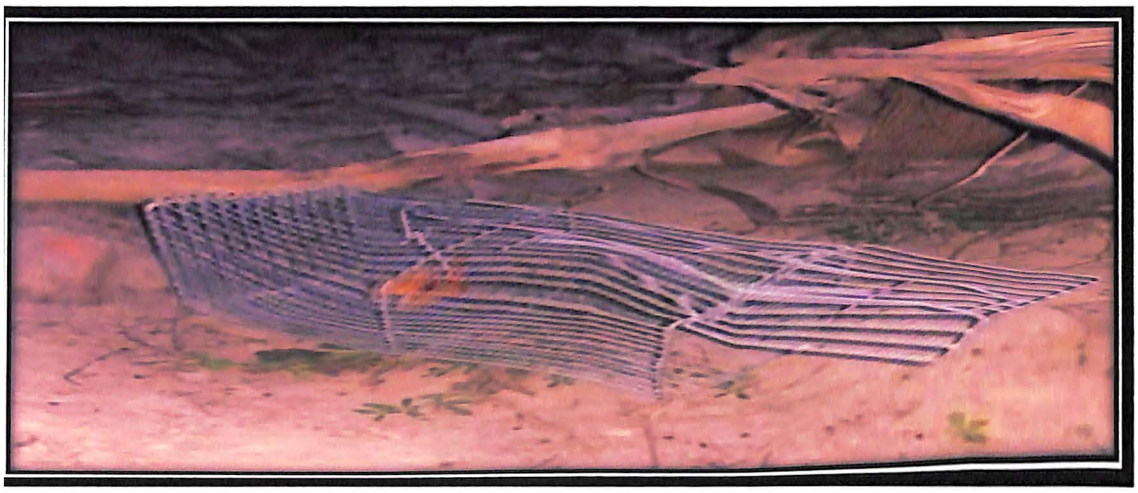


Fig. 9 Sherman Trap with lure

Fig. 10 Roof rat trapped inside Sherman trap

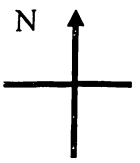
3.3 Evaluation of efficacy of various management practices against rodent damage

3.3.1 Experimental Site

The experiment was conducted in coconut orchards of Biraramchandrapur, Sakhigopal, Puri which is situated at 19° 58' 0" North latitude and 85° 49' 0" East longitude with an altitude of 19m above mean sea level (MSL) and at 21.5 km west of Bay of Bengal. The hottest month is May, with an average temperature of 30.4°C. Most precipitation falls in the month of August, with an average rainfall of 304 mm.

3.3.2 Experimental details and layout

Orchards with high rodent infestation rates were selected. The trial was conducted in a randomized block design (RBD) with five treatments and four replications, where each farmer represented one replication. One plot consisted of forty coconut trees.



T_1	IRRIGATION CHANNEL	T5	IRRIGATION CHANNEL	T3	IRRIGATION CHANNEL	T2
T2		T3		T5		T4
T3		T1		T4		T5
T4		T2		T1		T3
T5		T4		T2		T1

Fig. 11 Experimental Layout

3.3.3 Details of the treatments

Table 1: Treatments used in experiment

Treatment No.	Treatment Details
T_1	Crown baiting with Bromadiolone (0.005%) wax block @ 2 blocks/plant twice a year (30-35g) one on each side of the crown bearing tender nuts.
T_2	Trunk banding with specially designed polyester slippery sheet (45 cm width) at a height of 1.5 m.
T_3	Trunk banding with G.I sheet/zinc sheet (45 cm width) at a height of 1.5 m.
T_4	Trunk banding with polyethylene sheet (45 cm width) at a height of 1.5 m.
T_5	Untreated check

Crown cleaning of the coconut trees was done before implementation of each treatment.

3.3.4 Implementation of treatments

Crown baiting with bromadiolone (0.005%) wax block- The crown of the palms selected for crown baiting were cleaned. The wax blocks were inserted with thread at the centre and placed, one on each side of the crown. The procedure was again repeated after 6 months.

Trunk banding - The crown of the palms selected for banding were cleaned properly. The overlapping fronds were trimmed to restrict the movement of rats from one palm to the other. Polyester slippery bands of 45 cm width were banded around the tree trunk at a height of 1.5m. A similar procedure was followed for trunk banding with G.I sheet and polyethylene sheet.

3.3.4 Data recording:

The observation on fallen damaged nuts was taken on each coconut tree at one week before implementation of treatments during morning hours. After one week of

pre-treatment count, the treatments were implemented. The observation on fallen damaged nuts was taken at 2, 4, 6, 8 and 10 months after implementation of treatments. Then the nut fall reductions over pre-treatment count as well as over untreated check in per cent basis were calculated.

3.3.5 Statistical analysis

The data on number of fallen damaged nuts collected from different treatments were suitably transformed following Gomez and Gomez (1984). The transformed data were then subjected to statistical analysis. Statistical interpretation of data was done by following the Fischer's analysis of Variance technique at 5% level of significance. Critical differences were worked out whenever F test was significant.

3.4 Cost-benefit analysis of the treatments

The nut yield of 40 plants per acre was recorded from each farmer which was then converted to nut yield per hectare. Then cost benefit analysis was done considering nut yield and expenditure on labour charge and materials used.

$$\textbf{Increase in yield over control (\%)} = \frac{\text{Nut yield in treated trees} - \text{Nut yield in control palms}}{\text{Nut yield in control palms}} \times 100$$

3.5 Overall Impact assessment of adoption of social engineering activities against rodent control by farmers

Training on various social engineering activities against rodent control were conducted in Biraramchandrapur, Sakhigopal, Puri during the year 2015-2016 and 2016-2017. Various aspects of farmers towards rodent control were noted down before the training programme. After one month of training, a questionnaire was prepared regarding various social engineering activities that were imparted and distributed among the farmers. The data was noted down and per cent adoption was calculated.

Fig. 12 Experimental Plot at Biraramchandrapur, Puri

Fig. 13 Trunk banding with polyester slippery sheet

Fig. 14 Preparing bromadiolone wax block for crown baiting

Fig. 15 Crown baiting with bromadiolone wax block

Fig. 16 Banding the trunk with polyethylene sheet

Fig. 17 Trunk banding with G.I. sheet

Fig. 18 Training programme on rodent management at Biraramchandrapur, Puri, 2016-17

RESULTS

The results of present studies conducted on rodent pests of coconut pertaining to survey on extent of damage by rodents in Coastal Odisha, monitoring of rodent abundance in coconut plantations, efficacy of various rodent management practices and yield economics have been presented in suitable tables and figure.

4.1 Survey on extent of damage by rodents in various coconut orchards of Coastal Odisha.

The results on per cent rodent infested palms have been presented in Table 3. The highest per cent of rodent infested palms were recorded in Biraramchandrapur village of Puri district (50.70%) and the lowest per cent of rodent infested trees were recorded in Isaneswar farm, Konark of Puri district (2.63%).

The results on per cent nut damage are presented in Table 4. The highest per cent nut damage was recorded in Biraramchandrapur (26.1%) followed by Odomba (16.2%); Resinga (3.51%); Oterkera (3.35%) and Konark (1.08%).

4.2 Monitoring rodent pest abundance in coconut plantations

The results on trapping index (%) have been presented in Table 5. The highest trapping index (%) was recorded in Biraramchandrapur (12.41%) followed by Oterkera (9.81%) and Resinga (8.33%). The trapping index was found to be highest in the month of January and lowest in the month of August for all the three locations.

Table 2.Taxonomic position of the rodent pests associated with coconut plantation

Sl. No.	Common name	Scientific name	Sub-family	Family	
1	Roof rat/Black rat	*Rattus rattus* L.	Murinae	Muridae	Order: Rodentia Class: Mammalia
2	Lesser bandicoot	*Bandicota benghalensis* Gray	Murinae	Muridae	
3	Three stripped palm squirrel	*Funambulus palmarum* L.	-	Sciuridae	

Table 3: Survey on per cent rodent infested palms in various coconut orchards of Coastal Odisha during 2015-2016

SL.NO.	LOCATION		NO. OF TREES SURVEYED	NO. OF TREES WITH FALLEN DAMAGED NUTS	RODENT INFESTATION (RI %)
1.	BIRARAMCHANDRAPUR		355	180	50.70
2.	OTERKERA		178	36	20.22
3.	RESINGA		208	42	20.19
4.	ODOMBA		495	235	47.47
5.	KONARK	ISANESWAR FARM	950	25	2.63
		GOVT. FARM	1075	55	5.12

Table 4: Survey on per cent nut damage in some coconut orchards of Coastal Odisha during 2015-2016

SL.NO.	LOCATION	NO. OF DAMAGED NUTS	TOTAL NO. OF NUTS	NUT DAMAGE (%)
1	BIRARAMCHANDRAPUR	386	750	26.1
2	OTERKERA	78	467	3.35
3	RESINGA	73	421	3.51
4	ODOMBA	186	546	16.2
5	KONARK	256	618	1.08

Table 5: Trapping index (%) of different coconut orchards in Coastal Odisha during 2015-2016

	BIRARAMCHANDRAPUR				OTERKERA				RESINGA				
	1DOT	2DOT	3DOT	TI (%)	1DOT	2DOT	3DOT	TI (%)	1DOT	2DOT	3DOT	TI (%)	TI (%) MEAN
JULY	2	2	1	8.33	1	1	0	3.33	1	1	0	3.33	5.0
AUGUST	1	1	0	3.33	0	0	1	1.67	1	0	0	1.67	2.22
SEPTEMBER	1	1	1	5.0	0	1	1	3.33	1	0	0	1.67	3.33
OCTOBER	1	1	1	5.0	1	2	0	5.0	1	1	0	3.33	4.44
NOVEMBER	1	1	2	6.67	2	0	1	5.0	2	0	0	3.33	5.0
DECEMBER	6	4	5	28.33	5	4	4	21.67	4	5	3	20.0	23.33
JANUARY	6	5	7	30.0	5	7	3	25.0	5	4	4	21.67	25.57
FEBRUAURY	4	4	3	18.33	2	2	4	13.33	2	3	3	13.33	15.0
MARCH	3	1	3	11.67	2	3	1	10.0	3	1	1	6.67	9.45
MEAN				**12.41**				**9.81**				**8.33**	

DOT- Days of Trapping; TI (%) - Trapping Index

Table 6: Rodent species composition (%) of coconut orchards during 2015-2016

MONTH	R.r	B.b	F.p
JULY	55	45	-
AUGUST	94.74	5.27	-
SEPTEMBER	91.66	4.17	4.17
OCTOBER	93.33	3.33	3.33
NOVEMBER	100	-	-
DECEMBER	98.23	1.77	-
JANUARY	98.23	-	1.77
FEBRUAURY	100	-	-
MARCH	75	25	
MEAN	**89.57**	**9.39**	**1.03**

R.r- *Rattus rattus;* B.b- *Bandicota benghalensis*; F. p- *Funambulus palmarum*

Roof rat, *Rattus rattus* (89.57%) was found to be the dominant species in all the three coconut plantations followed by Lesser Bandicoot, *Bandicota benghalenis* (9.39%) and three stripped palm squirrel, *Funambulus palmarum* (1.03%). The data on monthly species composition has been presented on Table 6 that shows *R. rattus* dominating the coconut orchards in every month.

4.3 Evaluation of efficacy of various management practices against rodent damage.

The results on the efficacy of some management practices against rodent damage have been presented in Table 7. One week before implementation of treatments the average nut fall varied from 12.97 to 14.15 fallen nuts on all the palms under observation. At 2 months after implementation of treatments, T_2 i.e. trunk banding with polyester slippery sheet was significantly superior (0.02 fallen nuts) followed by T_1 i.e. trunk banding with G.I sheet (0.05 fallen nuts) in controlling the nut damage. T_2 and T_1 were found to be statistically at par with each other. Among all the treatments T_4 i.e. trunk banding with polyethylene sheet was proved inferior (2.4 fallen nuts) in controlling the nut damage.

At 4 months and 6 months after implementation of treatments, T_3 was found to be significantly superior (0.02 fallen nuts) followed by T_2 (0.05 fallen nuts) in controlling nut damage and both the treatments were statistically at par with each other. Among all the treatments T_4 was again found to be inferior (4.94 fallen nuts and 6.62 fallen nuts respectively) in controlling the nut damage.

A similar trend was observed with regard to nut fall at 8 months after implementation of treatments. T_3 proved to be most superior with zero nut fall followed by T_2 (0.02 fallen nuts) in controlling nut damage. Both the treatments were statistically at par with each other.

At 10 months after implementation of treatments both T_2 and T_3 were superior in controlling nut damage with zero nut falls in both the treatments. T_4 gave the lowest control among all other treatments (7.05 fallen nuts).

The per cent reduction in nut fall over pre-treatment count revealed trunk banding with G.I sheet as the best treatment (99.86 %) among other treatments followed by trunk banding with polyester slippery sheet (99.79 %) and crown baiting with

TABLE 7: Efficacy of various management practices against rodent damage in coconut plantations of Biraramchandrapur, Sakhigopal, Puri during 2016-17.

Tr. No.	TREATMENTS	PRE-TREATMENT NUT FALL COUNT (PTC)	POST-TREATMENT NUT FALL COUNT							
			2 MAT	4 MAT	6 MAT	8 MAT	10 MAT	MEAN	Reduction over PTC (%)	Reduction over UC (%)
1	Crown baiting with Bromadiolone (0.005%) wax block	14.15 (3.83)	0.4 $(0.94)^{b}$	1 $(1.22)^{b}$	1.52 $(1.42)^{b}$	0.45 $(0.96)^{b}$	1 $(1.21)^{b}$	0.87	93.82	94.29
2	Trunk banding with specially designed polyester slippery sheet	13.37 (3.72)	0.02 $(0.72)^{a}$	0.05 $(0.74)^{a}$	0.05 $(0.74)^{a}$	0.02 $(0.72)^{a}$	0.0 $(0.71)^{a}$	0.03	99.79	99.82
3	Trunk banding with G.I sheet/Zinc sheet	12.87 (3.66)	0.05 $(0.74)^{a}$	0.02 $(0.72)^{a}$	0.02 $(0.72)^{a}$	0.0 $(0.71)^{a}$	0.0 $(0.71)^{a}$	0.02	99.86	99.88
4	Trunk banding with polyethylene sheet	12.95 (3.67)	2.4 $(1.70)^{c}$	4.97 $(2.34)^{c}$	6.25 $(2.60)^{c}$	6.47 $(2.64)^{c}$	7.05 $(2.75)^{c}$	5.43	58.08	64.56
5	Untreated check (U.C)	13.65 (3.76)	14.42 $(3.86)^{d}$	13.8 $(3.78)^{d}$	15.32 $(3.98)^{d}$	16.77 $(4.16)^{d}$	16.92 $(4.17)^{d}$	15.45	-	-
SEm (±)		0.06	0.06	0.05	0.04	0.04	0.03	-	-	-
CD (P=0.05)		NS	0.18	0.14	0.13	0.11	0.11	-		

MAT- Months after Treatment; NS- Non-significant; Figures in the parenthesis are (X+0.5) square-root transformed values

Means followed by common superscript are not significantly different from each other.

bromadiolone wax block (93.82 %). The lowest per cent reduction in nut fall over pre-treatment count was observed in trunk banding with polyethylene sheet (58.08 %).

The per cent reduction in nut fall over untreated check was also found to be highest in case of trunk banding with G.I sheet (99.88 %) followed by trunk banding with polyester slippery sheet (99.82 %) and crown baiting with bromadiolone wax block (94.29 %). Trunk banding with polyethylene sheet had the lowest per cent reduction in nut fall over untreated check (64.56%).

4.4 Benefit-Cost Analysis

The cost: benefit analysis calculated for different treatments has been presented in Table 9. The highest nut yield of 7491 nuts per ha was recovered from T_3 (trunk banding with G.I sheet) followed by T_2 (7484 nuts per ha). But the highest incremental cost benefit ratio was exhibited by T_1 (1: 5.12) followed by T_2 (1: 2.07). The lowest cost benefit ratio was recovered from T_3 (1: 0.78).

4.5 Overall Impact assessment on adoption of various rodent management practices by farmers

The results on overall impact assessment have been presented in Table 10. The results revealed that before intervention no farmers were aware about crown baiting with bromadiolone (0.005%) wax block. But after intervention about 56.4% farmers followed the practice. Before intervention only 14.1% farmers knew about recommended dose of rodenticides but after intervention per cent adoption increased to 77.8%. Only 47.8% farmers practiced safe application of rodenticides before intervention but the per cent adoption increased to 100%. The per cent adoption in using mechanical traps in field before and after intervention was 23.6% and 86.6% respectively. Before intervention not a single farmer was aware of the practice of washing traps before reuse and collection of dead rodents and burring them in soil, but after intervention the per cent adoption of the practices increased to 40.1% and 65.2% respectively.

Table 8: Details of cost of treatments implemented in coconut orchard

Sl. No.	Parameters	Values of materials/ha			
		Bromadiolone cake	G.I Sheet	Polyester slippery sheet	Polyethylene sheet
1	No of trees/ha	100	100	100	100
2	Requirement/tree	4 blocks	4.5sq.ft	4.5sq.ft	4.5sq.ft
3	Requirement/ha	400 blocks	450 sq ft	450 sq ft	450 sq ft
4	Cost/ha	400X14/- = 6000/-	450X20/-=9000	450X12/-=5400	450X3/-=1350
5	Installation charge	6000/-	3060/-	3060/-	3060/-
6	Maintenance cost	-	18000	18000	18000
6	Total cost	12000/-	30060/-	26400/-	22410/-

Size of sheet: 3.0ft X 1.5ft = 4.5sqft

Table 9: Cost: Benefit analysis of various treatments against rodent damage in coconut orchard of Biraramchandrapur during 2016-2017

Treatments	Nut yield (Nuts/ha/yr)	Incremental Yield over Control (Nuts/ha/yr)	Value of Incremental Yield (Rs)	Cost of Treatment (Rs/ha)	Profit due to treatment (Rs)	Incremental Benefit Cost Ratio
T1: Crown baiting with bromadiolone (0.005 %) wax blocks	7072	4892	73380	12000	61380	5.12
T2: Trunk banding with polyester slippery sheet	7484	5304	79560	26460	53100	2.07
T3: Trunk banding with G.I sheet	7491	5311	79665	30060	49065	1.63
T4: Trunk banding with polyethylene sheet	4842	2662	39930	22410	17520	0.78
T5: Untreated Check	2180	-	-	-	-	-

Cost of nuts = Rs 15/nut, Cost of Bromadiolone wax blocks = Rs 15/block, Cost of polyester slippery sheet = Rs 12/sq.ft,

Cost of G.I sheet = Rs 20/sq.ft, Cost of polyethylene sheet = Rs 3/sq.ft, Labour charges for = Rs 30/man/palm

Table 10. Overall impact assessment on adoption of various rodent management practices by farmers during 2015-16 and 2016-2017

Sl.No	Rodent Control practices	Percent adoption	
		Before intervention	After intervention
1	Crown baiting with bromadiolone (0.005%)	0.0	56.4
2	Use of recommended dose of rodenticides	14.1	77.8
3	Safe application of rodenticides	47.8	100
4	Use of mechanical traps in field	23.6	86.6
5	Conducting the weeding operation	0.0	13.9
6	Washing of traps before reuse	0.0	40.1
7	Collection of dead rodents and burring in soil	0.0	65.2

CHAPTER- V

DISCUSSION

DISCUSSION

The results of various objectives under study are presented in Chapter 4 and are discussed in this chapter.

5.1 Survey on extent of damage by rodents in various coconut orchards of Coastal Odisha.

The Rodent Infestation rate (RI %) and nut damage (%) in various coconut farms of Coastal Odisha ranged from 2.63% to 50.7% and 1.08% to 26.1% respectively (Table 3 and 4). The highest per cent of rodent infested palms (50.71%) and nut damage (26.1%) was recorded in Biraramchandrapur village of Puri district.

According to NIPHM, the extent of loss in coconut plantations throughout India due to rodents ranged from 4.5 % to 55 %. Thus our present survey corroborates with the figures provided by NIPHM.

5.2 Monitoring rodent pest abundance in coconut plantations

The present investigation revealed that Roof rat, *Rattus rattus* L. was the predominant species in coconut plantations (89.57%) followed by *Bandicota benghalensis* Gray (9.39%) and *Funambulus palmarum* L. (1.03) (Table 6). Bhat (1992) has also reported *R. rattus* as a serious pest of orchards in the southern part of the country. Advani (1987) has reported Bandicoot rats causing damage in coconut nurseries and the Western Ghat squirrel, *Funambulus tristriatus* Waterhouse causing damage to the inflorescence of coconut trees in Western Ghat biome of South India.

Our present investigation recorded highest trapping index (%) in Biraramchandrapur village, Puri (12.41%) (Table 5). The mean trapping index was found to be highest in the month of January (25.57%) and lowest in the month of August (2.22%). High trapping index denoted high rodent population in coconut orchards. The reason was found to be barren crop fields left after harvesting of paddy which forced the rodents to move to coconut plantations. Our findings are supported by Bruggers (1979) who had also observed increased rat activity and damage within experimental plots shortly after harvest or land preparation in adjacent rice or corn fields. Reindinger and Libay (1980) also observed increased rat activity when nearby sweet potato and rice fields surrounding coconut experimental plots were harvested.

5.3 Efficacy of various management practices against rodent damage

The present investigation revealed that trunk banding with G. I sheet exercised better efficacy which was more or less similar to trunk banding with polyester slippery sheet (Table 7). The next better treatment was crown baiting with bromadiolone (0.005 %) wax blocks. All these three treatments reduced the nut fall by more than 90 %, highest being 99.86 % in trunk banding with G.I sheet.

Several workers have demonstrated that trunk banding with metal bands of plain galvanized iron could effectively reduce rat damage in coconut, provided the bands are kept in good repair and the overlapping fronds are regularly trimmed. Montenegro (1962) reported that a 23 cm wide plain G.I sheet wrapped around a palm trunk increased the number of harvestable nuts in study plots by 21.5 % over a 5 year period. Hoque (1973) recorded zero nutfall in 10 banded palms and 405 fallen damaged nuts in 10 reference palms during a 17 week observation. Thus our findings corroborates with the above findings. In case of crown baiting with bromadiolone (0.005%) wax blocks our findings revealed a mean nut fall of 0.4 fallen nuts at 2 months of treatment that increased to mean nut fall of 1 fallen nut and 1.52 fallen nuts at 4 and 6 months after treatment. The mean nut fall decreased to 0.45 fallen nuts at 8 months after treatment because of 2nd baiting. However, Reidinger and Libay (1980) reported that rat activity and fallen, damaged nuts decreased about 2 months after baiting and remained near zero thereafter. Thus our present finding is a deviation from the above finding.

5.4 Effect of treatments on economics of the study

The details of economics of study in terms of incremental benefit ratio have been presented in Table 9. The incremental cost benefit ratio was found to be highest in T_1 (crown baiting with bromadiolone wax blocks) *i.e.* 1: 5.12. Though T_3 was proved to be superior over other treatments in control of nut fall, the incremental cost benefit ratio was found to be lowest in this treatment *i.e.* 1: 5.78 because of high treatment cost.

The present study indicated positive returns from each treatment during this 10 month trial. However, Gallego *et al.* (1981) indicated a negative return from trunk

banding with G.I sheet during the first 2 years and a positive return starting in the third year. Thus the above finding does not match with the present finding.

CHAPTER- VI

SUMMARY AND CONCLUSION

with polyethylene sheet proved to be better in initial months but later on the nut fall started increasing, proving the treatment as not so good for long term purpose.

The cost benefit analysis was found to be highest in case of crown baiting with bromadiolone wax blocks (1: 5.12) followed by trunk banding with polyester slippery sheet (1: 2.07). Crown baiting with bromadiolone (0.005%) wax blocks was effective in controlling nut fall above 90% (93.82%) and did not require any further maintenance unlike trunk banding. Even though trunk banding with G.I sheet and polyester slippery sheet were found to be highly effective among all other treatments, these are the least preferred methods because of prohibitive costs of material, labour and maintenance requirements.

The results on impact assessment of farmers of Biraramchandrapur village, participating in rodent control practices during 2015-2016 and 2016-2017 revealed that before intervention, farmers were not practicing crown baiting. But 56.4% farmers started practicing crown baiting with bromadiolone (0.005%) wax blocks after intervention. Before intervention only 47.8% farmers were aware about safe application of rodenticides but after intervention 100% farmers used rodenticides safely at both houses and fields. Farmers were unaware about washing traps before reuse, but after intervention 40.1% farmers adopted the practice. Thus it may be concluded that per cent adoption of various rodent control practices increased to a high level after intervention. However further training on rodent damage and their management is required for generating awareness.

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