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Evaluation of various integrated rodent management modules in rice-vegetable cropping system at upper Brahmaputra valley zone, Assam

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Abstract
Four species of rodent pests *viz.*, *Bandicota bengalensis bengalensis, Mus booduga, Dremomys lokriah macmillani* and *Rattus sikkimensis* were recorded from the rice-vegetable cropping system of Allengmora village of Jorhat, Assam during 2016-17 out of which *B. bengalensis* was the most predominant species. Field experiments were carried out to evaluate the efficacy of five integrated rodent management modules against the rodent pests in *kharif* rice followed by *rabi* vegetables in rice-vegetable cropping system. All the modules showed superior over control. Among all modules of the present investigation, MII (cultural practices + castor oil as repellent + trapping with local bamboo traps + poison baiting with Zn phosphide and bromadiolone + burrow smoking) was found to be significantly superior with 72.9, 72.6, 78.8% at tillering, panicle initiation and harvesting stage of *kharif* rice and 67.4, 94.8, 80.3% control success in reduction of live burrow count at seedling, vegetative and harvesting stage of *rabi* vegetables respectively over control**.** The order of modules in terms of efficacy was MII>MI>MIV>MIII>MV. Module MII was recorded with highest benefit cost ratio of 1.34: 1 in *kharif* rice and 4.45: 1 in *rabi* vegetables among all followed by MI, MIV, MIII and MV in both the crops with efficacy in reduction of rodent population and their damage.

Keywords: Rodent pests, integrated management module, *kharif* rice, *Rabi* vegetables

Introduction

Rodents significantly affect crop production and livelihoods of farmers in both developed and developing countries but their impact as related to the choice and associated costs of management actions is poorly known [24]. In paddy cultivation one of the major limiting problems irrespective of system of cultivation right from nursery to harvest is the rodent pests [23]. Rodents inflict 0.44 to 60 percent tiller damage in paddy which accounts for 5-10 percent total grain yield losses in pre harvested rice [18]. Earlier it was reported that *Bandicota. Bengalensis* was the most predominant species with a relative abundance of 59.76 per cent, followed by 19.08 per cent *abundance of B. indica* and 15.42 per cent of *Mus booduga* and 5.82 per cent of *Rattus sikkimensis* in rice field of Assam [2]. Rodents attack almost all vegetable crops mostly at the seedling and mature stages [20]. In the arid region in Rajasthan, vegetables are severely affected by rodents probably due to their high water content [1]. The bandicoots (*B. bangalensis*) extend their burrows right beneath the watermelons and make holes in these to get their seeds and pulp [6]. Often the rodents nibble and gnaw the rinds of vegetables, like tomatoes, melons, and cucumbers etc., which quickly ferment and become unfit for human consumption [19]. Summer vegetable crops, particularly the cucurbits, often suffer severe damage by rodents [19] and damage to most of or the entire field of musk melons is not uncommon [13]. The irregular rodent outbreaks are sometimes responsible for extreme crop losses of 30-100%, occasionally leading to localized or widespread famine [8].

Methods for controlling rodent damage in rice eco system includes cultural practices such as field sanitation, trimming of field bunds and synchronized planting [14], trapping rodents in fields and premises [11, 4], fumigating the live burrows with natural smoke, hunting, physical barriers such as trap barrier system [17, 21], fumigating the rodent burrows with aluminium phosphide [3] and poison baiting with rodenticides [5, 22, 4]. Among all the available rodent control practices, use of rodenticides is the most common and expedient method [15]. But repeated and inappropriate use of rodenticides results in genetic resistance, bait shyness, Behavioural avoidance, non-target poisoning and environmental risks [7, 10, 9, 12].

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 [20]. An integrated management approach by adopting all the available management practices is more effective rather than relying on single rodenticides [22]. Due to variations in geographical and climatic factors; systems of crop production and post-harvest storage; carrying capacity of the environment; biology of the pest rodent species; the nature and extent of rodent problems and the perceptions and socioeconomic conditions of the people, no single strategy or method of control is feasible or applicable in all different pest situations [20]. Hence, the present investigation was aimed to evaluate the field efficacy of various integrated rodent management modules against rodent pests in rice-vegetable cropping system which are cost effective and eco-friendly too.

Materials and Methods

Study area

The present investigation was designed and carried out to evaluate the field efficacies of six different integrated rodent management modules (MI – M6) including control against rodent pests in rice-vegetable cropping system. The field trials were conducted at farmer's field of Allengmora in Jorhat district of Assam in a cropping system of *kharif* rice followed by *Rabi* vegetables during 2016-17. An area of about 40 ha having fairly good infestation of rodent pests with no previous record of rodenticide treatment for at least one season was selected. The study area was divided into four blocks following randomized block design (RBD). Each block (10 ha) represents one replication and consisted of six plots of 1 ha area for each treatment. These plots were separated by a distance of 0.45-0.50 ha between the plots as boarder area.

Management modules (treatment) imposed

The experiment was laid out in rice-vegetable fields with six treatments (modules) that were replicated in four blocks. For each module, various integrated rodent management operations were made and observations were recorded at three different stages *viz*., tillering, panicle initiation and harvesting stages of rice and seedling, vegetative and harvesting stages of vegetable crops to assess the per cent rodent control success of the various modules in reduction of rodent population and their damage at all the recorded stages of crop growth. During the study the integrated modules (treatments) designed were as in Table 1.

The cultural practices included removal of weeds, trimming or cleaning of bunds of the experimental area. Trapping included local bamboo traps, mechanical traps (Sherman trap) and bandicoot traps @ 30 traps/ha. For burrow fumigation, dry chilli powder, jute cloths, rice straw and egg tray plates were used with the help of a mechanical smoker. Castor oil (commercial product) and neem oil (commercial product) were used as repellent for application into live burrows as well as on bunds after moistening with pure water. For bromadiolone baiting, a ready to use bromadiolone (0.005%) cake was used. The bait materials used for zinc phosphide baiting were broken rice 960 g, mustard oil 20 ml and 20 g of zinc phosphide for preparation of 1 kg bait materials. For both the cases, banana sheath was used as bait stations which were placed near the live burrows. Pre baiting with plain bait (without poison) for two days was done in case of zinc phosphide. Burrow baiting with bromadiolone @ 10 g/burrow in capsule form wrapped with simple white paper.

Table 1: Modules evaluated for efficacy against rodents in rice-vegetable cropping system

Modules	Rodent management operation
MI	Removal of weed/bushes + Trimming/cleaning of bunds + Spraying of castor oil (1:20) on bunds at tillering stage of rice + Burrow Baiting with zinc phosphide at panicle initiation (PI) stage of rice + Trapping with local bamboo traps (30 traps/ha) at maturity stage of rice + Smoking in burrows with dry chilli powder (once in a month) + Bromadiolone baiting in burrows at vegetative stage of vegetables
MII	Removal of weed/bushes + Trimming/cleaning of bunds + Burrow application of castor oil @ 1 L/burrow at 1:20 dilution at tillering stage of rice + Baiting with zinc phosphide at bait station at PI stage of rice + Trapping with local bamboo traps @ 30 traps/ha at maturity stage of rice + Smoking in burrows with rice straw (Once in a month) + Bromadiolone baiting in bait station at vegetative stage of vegetables
MII	Removal of weed/bushes + Trimming/cleaning of bunds + Spraying of neem oil (1:20) on bunds at tillering stage of rice + Burrow baiting with bromadiolone at PI stage of rice + Trapping with mechanical (Sherman traps) @ 30 traps/ha at maturity stage of rice + Smoking in burrows with jute cloth (Once in a month) + Zinc phosphide baiting in burrows at vegetative stage of vegetables
MIV	Removal of weed/bushes + Trimming/cleaning of bunds + Spraying neem oil @ 1 L/burrow at 1:20 dilution at tillering stage of rice + Baiting with bromadiolone in bait station at PI stage of rice + Trapping with bandicoot traps @ 30 traps/ha at maturity stage of rice + Smoking in burrows with egg tray plates (Once in a month) + Zinc phosphide in bait station at vegetative stage of vegetables
MV	Removal of weed/bushes + Trimming/cleaning of bunds + Regular trapping (at monthly interval) with local bamboo traps one month after transplanting + Smoking in burrows with rice straw at harvesting stage of rice + Smoking in burrows with dry chillies at vegetative stage of vegetables (Once in a month) + Placing/Erecting burn owl nest boxes @ 1 no/ha
MV	Control

Assessment of module efficacy

The efficacy of modules was assessed in terms of per cent reduction in the rodent population and their damage incidence over control at tillering, panicle initiation and harvesting stage of rice and seedling, vegetative and harvesting stage of vegetables. The rodent population was assessed by live burrow count method, for which all the burrows in the study area are plugged a day before and freshly opened burrows in the next morning were counted. These active burrows were considered as index for rodent population. The rodent damage incidence in terms of per cent tiller damage was assessed by diagonal method in 75 hill samples/ha in rice and 75 plant samples/ha in vegetables were diagonally selected and counted the number of damaged (cut) and undamaged (uncut) tillers or plants and per cent rodent damage incidence (P.D.I.) was calculated as proposed earlier [16].

$$P.D.I. = A/(A+B) \times 100$$

Where

A = Total number of damaged tiller/seedlings or plants in 75 samples

B = Total number of undamaged tillers/seedlings or plants in 75 samples

Before and after imposition of treatments rodent population and damage incidence were recorded for each module at tillering, panicle initiation, harvesting stages of rice and seedling, vegetative growing and harvesting stage of vegetables. The data on per cent control success for each module at all the three stages were recorded [16].

Per cent control success = 100 (1- (T2 X C1)/(T1X C2)

Where

T1 = pre-treatment population of rodents/rodent infestation in treatment plots
T2 = post treatment population of rodents/rodent infestation in treatment plots
C1 = pre-treatment population of rodents/rodent infestation in control plots
C2 = post treatment population of rodents/rodent infestation in control plots

Results and Discussion

Rodent species composition

The predominant rodent species in rice-vegetable cropping system of Allengmora were *Bandicota bengalensis bengalensis* (Gray) (58%) followed by *Mus booduga* (26%), *Dremomys lokriah macmillani* (11%) and *Rattus sikkimensis* (5%).

Efficacy of modules

Live burrow count method

All the management modules studied during the experiment were superior over control in reducing the rodent population at all the three stages of both the crops i.e. at tillering, panicle initiation and harvesting stage of *kharif* rice and seedling, vegetative and harvesting stage of *Rabi* vegetables. Module MII (removal of weed/bushes + Trimming/cleaning of bunds + Burrow application of castor oil @ 1 L/burrow at 1:20 dilution at tillering stage of rice + Baiting with zinc phosphide at bait station at PI stage of rice + Trapping with local bamboo traps @ 30 traps/ha at maturity stage of rice + Smoking in burrows with rice straw (Once in a month) + Bromadiolone baiting in bait station at vegetative stage of vegetables) showed superiority in reduction of rodent population among all the modules with 72.9, 72.6 and 78.8% at tillering, panicle initiation and harvesting stage of *kharif* rice and 67.4, 94.8 and 80.3% at seedling, vegetative and harvesting stages of *rabi* vegetables respectively as depicted in Table 2.

Table 2: Efficacy of management modules in rice-vegetable cropping system in reduction of rodent population (LBC method), 2016-17

Module	Mean percent control success					
	Kharif (Rice), 2016-17			Rabi (Vegetables), 2016-17		
	Tillering stage	Panicle initiation stage	Harvest stage	Seedling stage	Vegetative stage	Harvest stage
M I	59.8	61.3	67.9	54.2	78.4	69.8
M II	72.9	72.6	78.8	67.4	94.8	80.3
M III	39.0	42.4	48.8	29.2	58.1	53.2
M IV	43.1	52.3	61.9	50.0	69.9	61.3
M V	28.0	36.8	45.5	20.8	43.2	38.4
MVI (Control)	-	-	-	-	-	-
F test	Sig	Sig	sig	Sig	Sig	Sig
CV (%)	8.46	6.26	6.43	12.30	7.48	9.51
Standard error mean	2.37	1.92	2.25	3.85	2.97	3.33
CD (P= 0.05)	7.73	6.25	7.33	15.13	9.70	10.85

In performance of the modules, MII was followed by MI (removal of weed/bushes + Trimming/cleaning of bunds + Spraying of castor oil (1:20) on bunds at tillering stage of rice + Burrow Baiting with zinc phosphide at panicle initiation (PI) stage of rice + Trapping with local bamboo traps (30 traps/ha) at maturity stage of rice + Smoking in burrows with dry chilli powder (once in a month) + Bromadiolone baiting in burrows at vegetative stage of vegetables) with 59.8, 61.3 and 67.9% control success at all the observed stages of *kharif* rice while 54.2, 78.4 and 69.8% per cent control success in seedling, vegetative and harvesting stages of vegetable crops respectively. During the investigation of efficacy in terms of per cent control success of different modules, the analysis of the pooled mean data showed MII to be superior followed by MI, MIV, MIII and MV (Table 3)

Table 3: Efficacy of management modules in rice-vegetable cropping system in reduction of rodent population (Pooled mean), 2016-17

Module	Mean number of live burrow/ha					
	Kharif (Rice), 2016-17			Rabi (Vegetables), 2016-17		
	Pre treatment	Post treatment	Per cent control success	Pre treatment	Post treatment	Per cent control success
M I	16.1	6.0	63.0	8.3	2.7	67.5
M II	14.4	3.8	74.8	6.3	1.2	80.8
M III	16.7	9.8	43.4	10	4.9	46.8
M IV	16.4	8.0	52.4	9.3	3.7	60.4
M V	18.0	11.4	36.8	10.7	7.3	34.1
M VI (Control)	21.2	22.2	-	12	13.3	-
F test	NS	Sig	sig	NS	Sig	Sig
CV (%)	-	35.45	5.56	-	58.23	5.15
Standard error mean	-	2.09	1.74	-	1.85	1.72
CD (P= 0.05)	-	6.58	5.66	-	5.84	5.62

Diagonal method

During the investigation of efficacy of modules in reducing damage incidence in terms of per cent cut tiller in rice/ per cent plant damage in vegetables, module MII was found to be significantly superior among all the modules to control the damage incidence with 89.6, 87.5 and 81.1% control at all the three stage of rice and 79.6 and 84.0% control success at vegetative and harvesting stage of vegetables respectively without any record of damage incidence at seedling stage of vegetables (Table 4).

The pooled data pertaining to per cent rodent control success against rodent damage incidence in various integrated modules revealed that all the modules showed significant difference among themselves. Based on damage incidence index, the order of modules in terms of efficacy in both the crops was found to be MII>MI>MIV>MII>MV (Table 5)

Table 4: Efficacy of management modules in rice-vegetable cropping system in reduction of per cent tiller /plant damage by field rodents (diagonal method), 2016-17

Module	Mean percent control success					
	Kharif (Rice), 2016-17			Rabi (Vegetables), 2016-17		
	Tillering stage	Panicle initiation stage	Harvest stage	Seedling stage	Vegetative stage	Harvest stage
M I	72.2	75.2	56.5	NIL	60.6	68.3
M II	89.6	87.5	81.1	NIL	79.6	84.0
M III	62.5	66.6	50.1	NIL	49.0	63.4
M IV	68.7	70.4	52.5	NIL	56.7	66.7
M V	52.6	54.2	25.5	NIL	39.1	54.4
M VI (Control)	-	-	-	-	-	-
F test	Sig	Sig	sig	-	Sig	Sig
CV (%)	2.40	12.47	8.66	-	8.31	4.08
Standard error mean	0.96	5.10	2.66	-	2.74	1.59
CD (P= 0.05)	3.12	16.62	8.66	-	8.92	5.17

Table 5: Efficacy of management modules in rice-vegetable cropping system in of per cent tiller /plant damage (Pooled mean), 2016-17

Module	Per cent tiller/plant damage/ha					
	Kharif (Rice), 2016-17			Rabi (Vegetables), 2016-17		
	Pre treatment	Post treatment	Per cent control success	Pre treatment	Post treatment	Per cent control success
M I	5.4	1.9	68.0	7.2	2.8	64.5
M II	4.4	0.7	86.0	6.9	1.3	81.8
M III	6.0	2.7	59.7	8.0	3.6	56.2
M IV	5.7	2.2	63.7	7.4	3.1	61.7
M V	6.2	3.7	44.1	8.1	4.6	46.8
M VI (Control)	6.7	7.6	-	8.5	9.7	-
F test	NS	Sig	sig	NS	Sig	Sig
CV (%)	-	47.56	6.90	-	34.19	5.19
Standard error mean	-	0.86	2.56	-	0.58	2.28
CD (P= 0.05)	-	2.71	8.35	-	1.70	8.97

Yield and benefit cost ratio

The present investigation revealed that all the tested modules recorded higher yield as compared to that of control. Paddy yield benefit per hectare over control was recorded higher in module MII with 25 quintal followed by MI, MIV, MIII and MV. Similarly, vegetable yield per hectare was recorded higher in MII with 200 quintal benefit over control followed by MI, MIV, MIII and MV (Table 6). The outcome of the present study on economics revealed that module MII was recorded with highest benefit cost ratio of 1.34 : 1 in *kharif* rice and 4.45 : 1 in *rabi* vegetables among all followed by MI, MIV, MIII and MV in both the crops with efficacy in reduction of rodent population and their damage.

Table 6: Efficacy of management modules over crop save in rice-vegetable cropping system

Module	Gross cost/ha (Rs.)	Estimated crop save						
		Kharif Rice			Gross cost/ha (Rs.)	Rabi Vegetables		
		Yield benefit/ha over control (q)	Monitary benefit/ha @ Rs. 12 per kg	Benifit cost ratio		Yield benefit/ha over control (q)	Monitary benefit/ha @ Rs. 10 per kg	Benefit cost ratio
M I	41665	24	28800	1.29: 1	101034	160	160000	4.05 : 1
M II	41145	25	30000	1.34: 1	100944	200	200000	4.45 : 1
M III	42625	18	21600	1.09: 1	101014	60	60000	3.06 : 1
M IV	42225	20	24000	1.16: 1	100959	130	130000	3.76 : 1
M V	43600	16.4	19680	1.02: 1	104534	49	49000	2.86 : 1
M VI (Control)	-	-	-	-		-	-	-

Module MII with cultural practices, trapping with local bamboo traps, burrow fumigation and Zn phosphide baiting was found to be the most promising module showing higher efficacy in reduction of rodent population and their damage and also recording higher benefit cost ratio in *kharif* rice and *rabi* vegetables in rice-vegetable cropping system. It was reported that integrated rodent management increased rice yield over conventional management based on synthetic rodenticides [22]. It was also reported that ecologically based rodent management practices are equally effective as typical practices for rodent management but more promising in combination with synthetic rodenticides [25]. Burrow smoking operation in all the stages of the crops at monthly basis offered better results along with trapping with local bamboo traps. It was also reported that bamboo traps in combination with synthetic rodenticides could be effective in management of rodent pests considering the performance and as well as their cost [4]. As bamboo traps are easily available at low cost and are most effective in performance as killed traps, so if we integrate it along with the poison baits and repellents then definitely the field population of rodent pests can be easily controlled by providing an eco-friendly management practices.

Conclusion

The data analysed from the present investigation revealed that module MII with cultural practices, burrow smoking, castor oil as repellent, trapping with local bamboo traps in combination with synthetic rodenticides was found the most superior one in effective management of rodent pests in rice-vegetable cropping system. Hence, management of rodent pests with ecologically based integrated approach comprising various components was found more promising, eco-friendly, cost effective and consistent with sustainable agricultural practices rather than implementing a single approach.

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