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Burrowing architecture and food hoarding behaviour of field rodents in rice- vegetable cropping system at upper Brahmaputra Valley Zone, Assam

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Abstract
The study revealed the burrow characteristics and food hoarding of three field rodents *viz.*, *Bandicota bengalensis bengalensis*, *B. indica* and *Mus booduga* prevalent in rice-vegetable cropping system of Jorhat, Assam during 2015-16 and 2016-17. Four burrows for each species from six plots each of 1 hectare area were excavated randomly including burrows both in field and bunds at two stages *viz.*, harvesting and post harvest stage of both *kharif* rice and *rabi* vegetables. For each burrow system the ten features were measured: the number and diameter of opening, length, diameter and depth of burrow tunnel, number and length of blind tunnels, number of side tunnels, number of food and brood chamber along with hoarded material and litter size per burrow. It was recorded that out of total live burrows count per ha 86 per cent burrows occupied by *B. bengalensis*, 9 per cent by *B. indica* and 5 per cent by *M. booduga*. All the recorded measurements were found to be highest at harvesting stage when the rodent activity was maximum and reduced at post harvest stage of both the crops when rodent activity was minimum. The hoarded material per burrow in *B. bengalensis* was recorded the highest 230.0 $\pm$ 48.27 gm and 83.40 $\pm$ 30.04 gm at post harvesting stage of vegetables and rice respectively. Both brood and food chamber of *B. bengalensis* and brood chamber of *M. booduga* were found shallower and smaller in size at post harvest stages as compared to harvesting stage of the crops. The average litter per burrow in both *B. bengalensis* and *M. booduga* revealed reduction in number after harvesting of the crops. The shallow nature of burrows suggests control of the field rats in rice-vegetable cropping system of Upper Brahmaputra Valley Zone, Assam could be improved by deep ploughing immediately after harvest of the crops to destroy the burrow system and expose the rodents to raptors and predators.

Keywords: Burrowing architecture, hoarding behaviour, *B. bengalensis*, *B. indica*, *M. booduga*

Introduction
Rodents are considered as the most important constraint upon the growing of rice [32, 38]. They cause significant damage to crops throughout the world [36] with yield losses of 5 – 15% in most countries [38]. The extent of rodent damage in rice reported in India ranges from 0.44-60.8% tiller damage [26]. It reported four rodent species associated with rice field in Assam out of which *Bandicota bengalensis* was the most predominant species with a relative abundance of 59.76%, followed by *B. indica* 19.08%, *Mus booduga* 15.42% and *Rattus sikkimensis* 5.82% [1]. Rodents were also found causing severe damage to vegetables at preharvest. It was reported from Assam that in a cropping system of rice followed by vegetables, the highest incidence of field rodents in terms of live burrow count (LBC) was recorded in pumpkin (36.60) followed by potato (34.40), pea (29.90), brinjal (28.80) and carrot (24.00). Among the vegetables, the highest damage was recorded in potato (14.46%) followed by pea (14.00%) and pumpkin (12.20%) [3].

Rodents are generally difficult to observe directly in the field. Most species are nocturnal in habit and they are often extremely wary of all potential predators, including humans. Under some circumstances, indirect signs of rodent activity, such as footprints or burrows may provide a good measure of rodent numbers and activity patterns. The burrowing trait in vertebrates evolved as early as the Carboniferous Period [21] and the resulting burrows vary greatly in diameter, depth and complexity: they impact geomorphology, hydrology, soil dynamics and vegetation pattern, etc. The lesser bandicoot rat (*Bandicota bengalensis*) excavates an extensive burrow system and is known for its underground food hoarding which exacerbates crop losses [22, 29, 27].

The bandicoot rats invade fields of rice just 1 or 2 weeks before harvest (after draining out last irrigation water) and quickly establish burrow systems, while in wheat crop, after 3-4 weeks of sowing, move to the interior of the field from the dikes [9, 22, 19]. Earlier workers [5] reported that the burrow system of *B. indica* as a single burrow having 3-4 openings, with a diameter of the tunnel as 8-15 cm and also found that burrow system of was organized in colonies of up to fifteen burrows and openings of burrow were very large and a single burrow system may spread over 300 m^2. Burrow systems of *B. indica* range from short tunnels (to 72 cm) used as feeding retreats, through to elaborate and extensive complexes with multiple chambers and entrances [10]. Some workers [42] reported that, in Northern India which experiences great variation in climatic condition between summer and winter, burrows of *M. booduga* have an average depth of 41 cm, as against 30 cm in southern India with less climatic fluctuation. Food hoarding is known in only half a dozen of the approximate 107 genera of Muridae family [45]. Among small mammals, the most thoroughly studied hoarder is the lesser bandicoot rat, a serious agricultural pest in southern Asia from Pakistan to Indonesia. The quantity of grain stored by lesser bandicoot rat has been well documented from Bangladesh, India and Pakistan because of its pest status and economic impact on rice and wheat productivity [29, 9, 14, 23]. As early as 1927 [46] to 1931 [4] it reported 600 ear heads of rice in some burrows studied in lower Sindh. In 1927, it was reported 93 kg of hoarded rice per hectare in Sindh which was equal to 10% of the total yield of the crop [14]. It was earlier reported that up to 450 kg/ha of various grains may be damaged due to food hoarding behaviour [24].

The present study was carried out to generate data on burrowing architecture and hoarding behaviour of field rodents in rice-vegetable cropping system and to use these data in devising a strategy for an effective Integrated pest management as very little information is known of the rodents in this particular cropping system of Assam.

Materials and Methods

Study area

The experiment was carried out at farmers field growing *kharif* rice followed by *rabi* vegetables of Bekajan village of Jorhat district, Assam during 2015-16 and 2016-17. The experimental sites are situated approximately 26.35^0 East latitude and at an altitude of 86.5 metres above mean sea level. The soil type of the location is acidic and sandy loam in texture.

Plan of work

Six fields each of 1 hectare area having fairly good infestation of rodent pests growing *kharif* rice followed by *rabi* vegetables were selected randomly for the predominant species *viz*., *B. bengalensis*, *B. indica* and *M. booduga*.

Burrow study

Identification of burrows

Four burrows for each species from the selected six fields were first identified based on certain characteristic features of different rodent species, such as:

1. The lesser bandicoot (*Bandicota bengalensis*) rat burrows revealed the presence of heaps of soil covering the openings located at different points of burrow.
2. The burrows of the Indian field mouse (*Mus booduga*) could be distinguished from those of other rodent species by smaller openings of about one centimeter with scooped soil before the burrow opening.
3. The large bandicoot rat (*Bandicota indica*) burrows were recognized by the fresh, wet globules of soil and soft faecal matter at the burrow opening. Fresh foot prints and tail marks near burrow also indicators of live burrows.

Excavation of burrows

Identified burrows were selected randomly to record burrowing characteristics at harvesting stage and post harvest stage of both the *kharif* rice and *rabi* vegetable crops. Before excavating of the selected burrows all piles of soil dirt were removed to the ground level. Active entrance was selected as the starting point to excavate the burrow system. The burrows were excavated with the help of a spade and shallow digging tools. While digging proceded, the recovered hoarded food material was carefully separated from soil dirt, grass and stalk cuttings and stored the food material in plastic bags and then weighed per burrow in fresh. After complete recovery of the hoarded material, all the necessary measurements of burrowing features were taken for each burrow system.

Measurements of the positions marked by wooden pegs were taken with the help of measuring tape. Length, width and depth of the burrows, diameter of the burrow openings, length of blind tunnel and diameter of the tunnel were measured. Number of the openings of the burrow, number of the side tunnel, number of the food chambers and different types of hoarding materials in the burrow was also recorded. Presence of litters in each burrow was also taken into consideration and litter size was recorded.

Hoarding behaviour

During the digging of burrows, care was taken to collect various types of food materials hoarded inside the burrows of all the rodent species in the fields of rice and vegetables of rice-vegetable cropping system. The hoarded grains, ear heads of crops, vegetables and other materials inside the burrows were collected in a polythene bag and categorized. Weights of the hoarded materials were measured.

Results and Discussion

Distribution of rodent burrow density

The mean burrow number of field rodents per hectare was recorded as 12 (12.16 $\pm$ 3.18) and 5 (5.16 $\pm$ 4.11) at harvesting and post harvesting stage of *kharif* rice and 16 (15.66 $\pm$ 8.57) and 9.6 (9.66 $\pm$ 4.84) at harvesting and post harvesting stage of vegetables of rice-vegetable cropping system showing lower field rat population on the experimental fields. Out of these burrows 68 per cent burrows were recorded in the bunds of the field and 12 per cent in the big bunds at harvesting stage while 72 per cent within the field and 28 per cent in the big bunds at post harvest stage of *kharif* rice. Likewise, 80 per cent and 20 percent burrows were recorded from small bunds within fields and big bunds respectively at harvesting stage and 42 per cent and 58 per cent within field and big bunds respectively at post harvest stage of the vegetable crops. Identification of burrows on the basis of methods given [40] where burrow of *M. booduga* was recognized by presence of scooped soil at the entrance of the burrow opening of 1 cm diameter, presence of wet globules of fresh earth and soft faecal matter in the burrow opening in *B. indica* and the burrow opening was characteristically covered with heap of dug out soil which were small lumps of soil in case of *B. bengalensis*. It was recorded that out of total live

burrows count per hectare 86 per cent burrows occupied by *B. bengalensis*, 9 per cent by *B. indica* and 5 per cent by *M. booduga*. It was also earlier reported that *B. bengalensis* was the most predominant species in various habitat in Jorhat district of Assam [13].

Burrowing architecture of field rodents

Burrow system *of Bandicota bengalensis bengalensis*

Ten burrowing features were recorded during the present study as outlined in Table 1. The study showed that at harvesting stage of the *kharif* rice, burrow of *B. bengalensis* was recorded with an average of 606 cm in total length and 67.33 cm in depth when the rodent activity was maximum. The diameter of tunnel was recorded as 8.63 cm. While at post harvest stage of the crop the length of the tunnel was reduced to 334 cm with 34 cm in depth and 5.7 cm in diameter when rodent activity was minimum. The diameter of the burrow opening was also reduced from 6.63 cm at harvesting stage to 6 cm at post harvest stage of the crop along with the reduction in number of openings from 5.33 to 2.66. Likewise, the number of blind tunnels along with length also decreased from the harvesting stage to the post harvest stage. But the number of food chamber was recorded as one in both the stages of the crop. The burrow system of *B. bengalensis* was found simple type as shown in Fig 1-A. The length, depth and number of burrow opening of *B. bengalensis* as recorded in the present investigation was more or less equal to the findings of earlier workers in West Bengal [9]. It also reported varied number of surface openings from 1-16, depth and extension of a burrow system ranged from 30 to 100 cm and 4.3 to 45 m, respectively. Earlier, it also reported 0-7 food chambers, 1-16 burrow openings in the burrow system of *B. bengalensis* from the wheat field of Bangladesh [23]. Similar trend was also recorded in the vegetable crops where there was reduction in length, depth and diameter of the tunnel from harvesting stage to post harvest stage of the vegetables. But the number of food chamber recorded in vegetable crops was comparatively more such as 2-3 in numbers as compared to single in rice field during the investigation. The present study also revealed that the length and depth of burrow in vegetable field was less as compared to those of rice field. On the other hand, the diameter of the opening was recorded slightly higher 9.33 ± 1.61 at harvesting and 6.50 ± 0.45 at post harvest stage of vegetables as compared to those of 8.63 ± 0.61 and 5.7 ± 0.50 at harvest and post harvest stage respectively of rice field. The mean diameter of the burrow openings varied with the stages of the crop and climatic condition [39].

The study revealed that the burrow usually branched off into several tunnels distributed in different directions. The branching was not uniform. The tunnel passageways were almost circular and were widened at the junctions where branching was seen. Most of the burrows excavated revealed the presence of a deeper blind tunnel which was frequently associated with the nest area. Some extra-ordinary values have been recorded for *B. bengalensis* burrow by various authors such as, a maximum length of 2030 cm in an estimated area of 50 m^2 of the burrow system of *B. bengalensis* in earlier works [33]. The variations in dimensions of the burrow systems measured in current study from the observations of others have been related to physical properties as given earlier [28] and texture of soil [35]. The variations in many characteristics of burrow systems recorded presumably related to the nature of crops, seasons, soil and its moisture content. The present study also revealed the presence of single brood chamber at the recorded crop stages in both the seasons which was in accordance with report given in 1981 [15] where recorded single brood chamber in the burrow system of *B. bengalensis.*

Table 1: Burrowing characteristics (Mean ± Sd) of *B. bengalensis* in rice-vegetable cropping system

Season	Crop stage	Month	Total length of burrow (cm)	Depth of burrow (cm)	Diameter of tunnel (cm)	No. of openings	Diameter of opening (cm)	No. of blind tunnels (cm)	Length of blind tunnels (cm)	No. of side tunnels	No. of food chambers	No. of brood chamber
Winter (Rice)	Harvesting	November	606.0 ±7.21	67.33 ± 4.04	8.63 ± 0.61	5.33 ± 0.57	6.36 ± 0.37	3.33 ± 0.57	54.53 ± 1.15	4.33 ± 0.57	1.0 ± 0.0	1.0 ± 0.0
	Post Harvest	December	334.0 ± 9.53	34 ± 3.60	5.7 ± 0.50	2.66 ± 0.57	6.0 ± 0.26	2.33 ± 0.57	50.66 ± 1.01	2.66 ± 0.57	1.0 ± 0.0	1.0 ± 0.0
Spring (Vegetables)	Harvesting	April	587.0 ± 21.37	58.66 ± 3.05	9.33 ± 1.61	4.66 ± 0.57	6.33 ± 0.15	3.33 ± 0.57	57.56 ± 2.09	4.66 ± 0.57	2.33 ± 0.57	1.0 ± 0.0
	Post Harvest	May	395.66 ± 14.36	31.0 ± 2.0	6.50 ± 0.45	3.33 ± 0.57	5.76 ± 0.35	3.0 ± 0.0	52.46 ± 1.16	2.66 ± 0.57	3.00 ± 0.70	1.0 ± 0.0

Table 2: Burrowing characteristics (Mean ± Sd) of *B. indica* in rice-vegetable cropping system

Crop	Crop stage	Month	Total length of burrow (cm)	Depth of burrow (cm)	Diameter of tunnel (cm)	No. of openings	Diameter of opening (cm)	No. of blind tunnels (cm)	Length of blind tunnels (cm)	No. of side tunnels	No. of food chambers
Kharif Rice	Harvesting	November	551.66 ± 24.66	101.33 ± 3.51	12.30 ± 0.90	3.33 ± 0.57	8.83 ± 0.41	2.66 ± 0.57	70.66 ± 1.55	3.33 ± 0.57	0.0
	Post Harvest	December	302.66 ± 7.50	44.0 ± 3.0	8.86 ± 0.47	2.66 ± 0.57	7.16 ± 0.15	2.33 ± 0.57	61.20 ± 0.90	2.66 ± 0.57	0.0
Rabi Vegetables	Harvesting	April	568.66 ± 25.77	93.33 ± 3.78	12.06 ± 0.77	3.66 ± 0.57	9.90 ± 1.05	2.66 ± 0.57	77.23 ± 1.05	3.66 ± 0.57	0.0
	Post Harvest	May	340.66 ± 17.21	40.2 ± 0.90	9.26 ± 0.96	3.33 ± 0.57	7.56 ± 0.65	2.66 ± 0.57	70.46 ± 2.07	2.33 ± 0.57	0.0

Table 3: Burrowing characteristics (Mean ± Sd) of *Mus booduga* in rice-vegetable cropping system

Crop	Crop stage	Month	Total length of burrow (cm)	Depth of burrow (cm)	Diameter of tunnel (cm)	No. of openings	Diameter of opening (cm)	No. of blind tunnels (cm)	Length of blind tunnels (cm)	No. of side tunnels	No. of food chambers	No. of brood chamber
Kharif Rice	Harvesting	November	88.23 ± 4.75	15.66 ± 0.90	2.33 ± 0.15	2.0 ± 0.0	2.50 ± 0.20	1.33 ± 0.57	22.23 ± 1.00	1.66 ± 0.57	0.00	1.0 ± 0.0
	Post Harvest	December	69.50 ± 2.29	7.06 ± 0.25	2.01 ± 0.17	2.00 ± 0.00	2.22 ± 0.10	1.00 ± 0.00	17.70 ± 0.45	1.33 ± 0.57	0.00	1.0 ± 0.0
Rabi Vegetables	Harvesting	April	108.66 ± 4.04	13.00 ± 1.00	2.30 ± 0.20	2.00 ± 0.00	2.36 ± 0.15	1.33 ± 0.57	23.96 ± 1.07	2.00 ± 0.00	0.00	1.0 ± 0.0
	Post Harvest	May	70.33 ± 2.51	6.20 ± 0.26	2.03 ± 0.20	2.00 ± 0.00	2.16 ± 0.15	1.00 ± 0.00	20.36 ± 0.90	1.33 ± 0.57	0.00	1.0 ± 0.0

Table 4: Hoarding behaviour and litter size of field rodents ((Mean ± Sd) in rice-vegetable cropping system

Species	Crop stage	No. of food chambers	Materials hoarded	Weight of hoarded material (gm)	No. of litters/ burrow
Bandicota bengalensis	Harvesting (rice)	1.0 ± 0.0	Rice grains	62.40 ± 14.53	4.80 ± 0.83
	Post-Harvest (rice)	1.0 ± 0.0	Rice grains	83.40 ± 30.04	3.80 ± 0.83
	Harvesting (vegetables)	2.33 ± 0.57	Half eaten brinjal, half eaten potato tubers	150.0 ± 34.20	5.00 ± 0.70
	Post-Harvest (vegetables)	1.66 ± 0.57	Half eaten brinjal, half eaten potato tubers	230.0 ± 48.27	3.6 ± 0.54
Mus booduga	Harvesting (rice)	0.00	-	-	3.40 ± 0.54
	Post Harvest (rice)	0.00	-	-	2.40 ± 0.54
	Harvesting (vegetables)	0.00	-	-	4.00 ± 0.60

Table 5: Architecture of food and brood chamber of field rodents in rice-vegetable cropping system

Species	Crop stage	No. of food chamber	Size of food chamber (length in cm X breadth in cm)	Depth of chamber from top soil surface (cm)	No. of brood chamber with juveniles	Size of brood chamber length in cm X breadth in cm)	Depth of brood chamber from soil surface (cm)
Bandicota bengalensis	Harvesting (rice)	1.0 ± 0.0	(18.33 ± 3.31) X (23.0 ± 2.0)	32.66 ± 1.52	1.0 ± 0.0	(19.66 ± 1.52) X (19.33 ± 2.08)	28.0 ± 1.0
	Post-Harvest (rice)	1.0 ± 0.0	(20.66 ± 2.51) X (25.33 ± 1.52)	31.0 ± 1.0	1.0 ± 0.0	(18.66 ± 0.56) X (18.0 ± 1.0)	25.0 ± 1.0
	Harvesting (vegetables)	1.60 ± 0.54	(22.0 ± 1.0) X (10.0 ± 1.0)	27.0 ± 2.0	1.0 ± 0.0	(22.66 ± 0.57) X (22.0 ± 1.0)	23.33 ± 0.57
	Post-Harvest (vegetables)	3.00 ± 0.70	(24.0 ± 1.0) X (13.33 ± 0.57)	19.66 ± 1.52	1.0 ± 0.0	(17.66 ± 1.15) X (17.0 ± 1.0)	17.33 ± 0.57
Mus booduga	Harvesting (rice)	-	-	-	1.0 ± 0.0	(6.5 ± 0.50) X (6.83 ± 0.76)	14.33 ± 0.76
	Post-Harvest (rice)	-	-	-	1.0 ± 0.0	(4.83 ± 0.57) X (5.50 ± 0.50)	7.8 ± 0.76
	Harvesting (vegetables)	-	-	-	1.0 ± 0.0	(7.66 ± 0.57) X (8.16 ± 0.57)	10.66 ± 1.04

Food chamber and brood chamber

Usually the food chambers were built in middle of the tunnel passageways and occasionally noticed at the end of the blind tunnels. The length and breadth of food chamber at post harvest stage of rice was recorded larger (20.66 ± 2.51) cm X (25.33 ± 1.52) cm in size when the rodent activity was maximum as compared to harvesting stage (18.33 ± 3.31) cm X (23.0 ± 2.0) cm when the rodent activity was minimum and the same trend was also recorded in vegetable crops (Table 5).The observed food chamber was located at a depth of 32.66 ± 1.52 cm from surface soil at harvesting stage but it became shallow at post harvest stage of the crops. Likewise in vegetable crops the depth of food chamber was deeper at harvesting stage as compared to post harvest. The depth of food chamber was recorded shallower in vegetable crops than those recorded in rice crop at both the stages. The observed food chamber of *B. bengalensis* during the harvesting and post harvest stages of rice crop was oblong to spherical in shape and filled with rice ear heads (Plate 1-A). In earlier reports, It was mentioned that the nest chamber of *B. bengalensis* had spherical to oblong shape [20] which supports the present investigation. But in case of food chamber observed in vegetable crops was irregular in shape with some extended small tunnel ends like a star with half eaten brinjal (Plate 2.-A&B), globular with half eaten potato as shown in Plate (2- C).

The brood chamber studied during the experiment was found larger in size at harvesting stages of both the crops as compared to those observed at post harvest stage. The largest size (length X breadth) of the chamber was recorded (22.66 ± 0.57) cm X (22.0 ± 1.0) cm at harvesting stage of vegetable crops followed by (19.66 ± 1.52) cm X (19.33 ± 2.08) cm at harvesting stage of rice. The depth of brood chamber also found shallower at post harvest stage of the crops as compared to harvesting stage of the crops (Table 5). The mean litter size per burrow was recorded the highest (5.00 ±

0.70) in number at harvesting stage of vegetables followed by 4.80 ± 0.83 at harvesting stage of rice, 3.80 ± 0.83 and 3.6 ± 0.54 at post harvest stages of rice and vegetables respectively (Table 4). It was earlier recorded that *B. bengalensis* had two seasonal peaks of breeding i.e. September–October and January- March [2] which in the present investigation was related to the maturity stage of both the crops.The brood chamber observed during the study was somewhat spherical or oblong in shape and the chamber was padded with various materials like rice straw, grasses etc (Plate.1-B). The brood chamber was located at the middle part of the tunnel.

Hoarding habits

The various hoarded material observed (Table 4) in the burrows of *B. bengalensis* was rice grain with stalk, in food chamber, grasses and polythene pieces, rice straw was used lining the nest chamber. It was revealed that the hoarded materials other than food grains included grass stems, leaves of paddy plants, pieces of cloth and paper [8]. The weight of the hoarded material was recorded the highest 230.0 ± 48.27 gm at post harvest stage of vegetable crops followed by 150.0 ± 34.20 gm at harvesting stage and 83.40 ± 30.04 gm and 62.40 ± 14.53 gm at post harvest and harvesting stage of rice respectively.

Burrow system *of Bandicota indica*

The present study showed that the average length of the burrow of *B. indica* varied from 551.66 ± 24.66 cm at harvesting stage when rodent activity was maximum to 302.66 ± 7.50 cm at post harvest of rice when rodent activity was minimum with 101.33 ± 3.51 and 44.0 ± 3.0 cm depth respectively (Table 2). It was also reported that the total length of *B. indica* burrows excavated ranged from 44 to 520 cm [5]. The diameter of burrow opening was recorded the highest 9.90 + 1.05 cm at harvesting stage of vegetables followed by 8.83 + 0.41 cm at harvesting stage of rice crop. There was no record of any brood or food chamber in the burrow system of *B. indica* during the study. These burrows might be used for the purpose of temporary shelter to indulge in feeding (Fig. 1-B). Maximum burrows of *B. indica* were observed in the field bunds. The number of surface opening was recorded as 3.66 ± 0.57 at harvesting stage of vegetables followed by 3.33 ± 0.57 at harvesting stage of kharif rice. The findings of present investigation was more or less similar to earlier reports [39] and stated that the burrow system may be simple consisting of an unbranched tunnel upto 700 cm in length and 6-14 cm in diameter with 1-13 openings leading to tunnel with a diameter of 6-24 cm. Depth may range from 40-60 cm and extending to a maximum length of 9 m. It was reported that during harvest they turn grainivorous on harvested paddy and also eat vegetables as well as ground dwelling birds [10].

Burrowing system *of Mus booduga*

During the present study the burrow length of *M. booduga* was recorded the highest (108.66 ± 4.04 cm**)** at harvesting stage of the vegetable crops followed by 88.23 ± 4.75 cm at harvest stage of rice with 2.36 ± 0.15 cm and 2.50 ± 0.20 cm in diameter of burrow opening respectively (Table 3) when rodent activity was maximum. It was earlier observed that *M. booduga* created long (30-90 cm) burrows with small (2.5-3.75 cm in diameter) in openings in Thar deserts [16]. The depth of burrow was recorded highest at harvesting stage of both the crops as compared to those at post harvest stage of the crops when the rodent activity was minimum. The length of blind tunnels at post harvest stage was also less as compared to those at harvest stage. From the observations, it showed that the further burrowing activity was reduced just after harvesting of the crop irrespective of crop type. During the study no food chamber observed in the burrow system of *M. booduga* but presence of one brood chamber with juveniles at both harvesting and post harvest stage of both the crops was recorded. The mean number of surface opening of the burrow was recorded 2.00 ± 0.00 at all the two stages irrespective of the crop type. Earlier workers [40] reported that burrows of *M. booduga* have 2-4 surface openings with a depth of 50-60 cm and length ranging from 45-65 cm. The burrows have 1-2 nesting chambers and have smaller openings compared to other species. The one cm opening is characterised by scooped soil at the entrance with small pebbles. Unlike other rodents burrows of *M. booduga* was simple and shallow. The burrows could be distinguished from those of other rodent species by smaller opening of about one cm with scooped soil before the burrow opening. The present study showed a mean diameter of burrow opening 2.50 ± 0.20 cm at harvesting stage followed by 2.22 ± 0.10 cm at post harvest of rice crop whereas it was found 2.36 ± 0.15 cm and 2.16 ± 0.15 cm at harvest and post harvest of vegetable crops respectively. Similar findings were made by earlier workers [12]. The diagram of burrowing system of *M. booduga* was shown in Fig. 1-C.

Brood chamber

There was one brood chamber observed at all the recorded stages of the crops. The length and breadth of the brood chamber (Plate 3-A, B, C) of *M. booduga* at harvesting stage was found larger (6.5 ± 0.50) cm X (6.83 ± 0.76) cm than (4.83 ± 0.57) cm X (5.50 ± 0.50) cm at post harvest stage of rice crop at a depth of 14.33 ± 0.76 cm and 7.8 ± 0.76 cm respectively (Table 5). The litter size per burrow was found the highest 4.00 ± 0.60 in number at harvesting stage of vegetables followed by 3.40 ± 0.54 at harvesting stage and 2.40 ± 0.54 at post harvest stage of rice crop (Table 4). Those results are in conformity with the findings of earlier workers [6, 12]. The brood chamber with juveniles recorded was globular in shape and lined with rice straw. The inlet tunnel of *M. booduga* ended in a chamber resembling the nest chamber, but without bedding. Similar observations was also reported by earlier workers [42] which is supporting the present study.

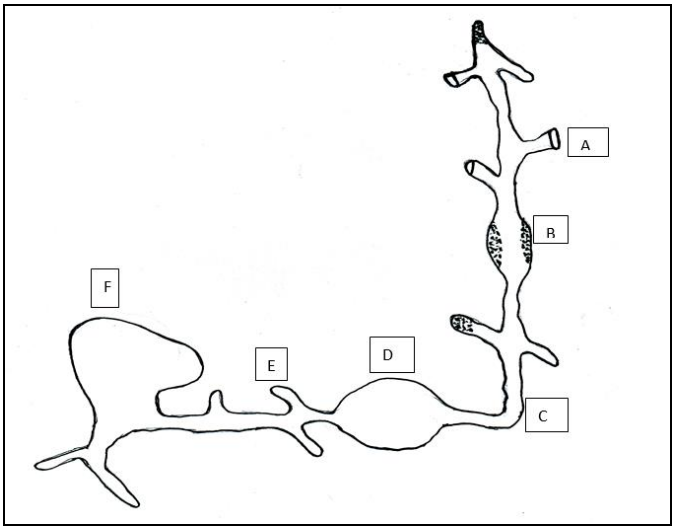

Fig 1-A: Burrow system of *Bandicota bengalensis* (A-opening, B-Soil dirt piles, C-Main tunnel, D-Brood chamber, E-Blind tunnel, F-Food chamber)

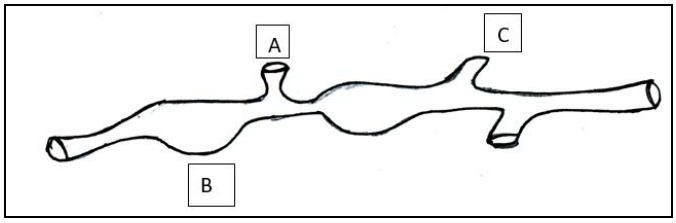

Fig 1-B: Burrow system of *Bandicota indica* (A-opening, B-chamber, C- blind tunnel)

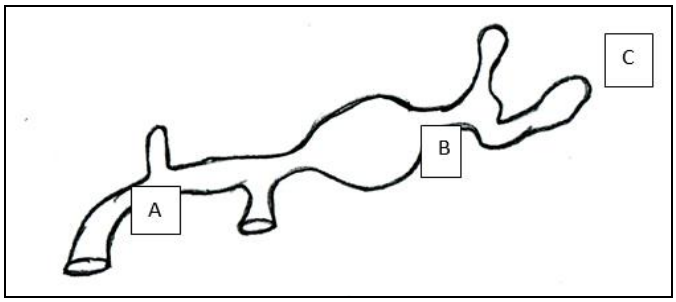

Fig 1-C: Burrow system of *Mus booduga* (A- opening, B-brood chamber, C-ended chamber)

A. B. C.

Plate 1: (A) Brood chamber of *Mus booduga* with Juveniles lined with rice straw, **(B)** Juveniles of *M. booduga* **(C)** Brood chamber within the burrow system

A. B.

Plate 2(A): Food chamber of *Bandicota bengalensis* in rice field, **(B)**: Brood chamber with juveniles of *B. bengalensis*

A. B. C

Plate 3(A), (B), (C): Food chamber of *B. bengalensis* in vegetable field

Hoarding habits

The burrows of *Mus booduga* did not contain any hoarded material except the lined material of the brood chamber like rice straw, grasses, leaves of neighboured crops etc. Similar observations were made by other workers [44, 33]. The new information about the characteristics of burrow system of the field rodents in rice-vegetable cropping system of Jorhat suggests practical opportunity for improving control of these field rodent pests. Deep ploughing of fields immediately after harvest of crops would destroy the burrow system and may expose the animals to increased predation by raptors and predators. Future research should explore the relationship between burrow attributes and soil structure, texture and moisture contents; availability of food and cover; and life cycle phases of the rodent species.

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