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Burrow Characteristics of Lesser Bandicoot Rat (*Bandicota bengalensis*) in the Agro-Ecosystem of Pothwar Plateau, Pakistan

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ABSTRACT

The study reveals the burrow characteristics and food hoarding of the lesser bandicoot rat (*Bandicota bengalensis*) in the agro-ecosystem of Pothwar, Pakistan. We excavated 8 burrows in sorghum and groundnut crops and 5 burrows in wheat crops at the time of crop maturity, and 9 burrows on crop field boundaries during the non-crop summer season. For each burrow system we measured: the number and diameter of burrow openings, length, diameter and depth of burrow tunnels, number of chambers and amount of hoarded materials. Burrows in wheat crops were significantly shorter and the burrows on crop field boundaries were significantly shallower than those excavated in other habitats. Averaged over all 30 burrow systems, burrows had 2.1 number of openings with diameter of 8.3 cm. Burrow tunnels averaged 8.9 m long, 3.9 cm diameter wide and were 11.5 cm below ground surface. Each burrow system had 1.8 chambers. Hoarded material was recorded in 28 (93.3%) burrows, with a dry weight of hoarded food of 14.7 g per burrow. The shallow nature of the burrows suggests control of the bandicoot rat in Pothwar croplands could be improved by deep ploughing immediately after harvest of crops to destroy the burrow systems and expose the rats to raptors and predators.

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Authors' Contributions
IH conceived and designed the experimental work. NAQ helped in designing the experiment and executed the filed experiment. MA and MM assisted in field experiments and data analysis.

Key words
Burrow pattern, hoarding behaviour, rodent control, rodent damage, small mammals.

INTRODUCTION

The lesser bandicoot rat (*Bandicota bengalensis*) is a widely distributed rodent pest species of southern and southeastern Asia. Pakistan has two isolated populations of this rat, one throughout central and northern Punjab and in the southern part of Khyber Pakhtunkhwa province, and the other in the southern Sindh (Roberts, 1997; Smiet *et al*., 1978). Losses to standing crops in Pakistan from bandicoot rat damage have been estimated at 6-19% in rice (Greaves *et al*., 1977; Fulk, 1977; Fulk and Akhtar, 1981; Khan, 1987), 2-7.5% in wheat (Beg *et al*., 1977, 1978; Fulk *et al*., 1980a; Ahmad *et al*., 1986a), 7-11% in sugarcane (Beg *et al*., 1979; Fulk *et al*., 1980b), and 3-5 % in groundnut (Roberts, 1981; Brooks *et al*., 1988). In a field experiment on rodent (predominantly bandicoot rat) control in groundnut crops of Pothwar area, Khan *et al*. (2009) reported an increase of more than 60% in the crop yield in treated versus non-treated fields.

This rat excavates an extensive burrow system and is known for its underground food hoarding which exacerbates crop losses (Parrak, 1969; Roy, 1974; Rao, 1980). For example, the bandicoot rat in Garhwal Himalaya, India stored an average of 390 g of wheat panicles per burrow with as much as 2 kg in one burrow (Sheikher and Malhi, 1983; Malhi, 1986). Sheikher and Jain (1991) have reported 486 g ear heads of wheat per burrow system in Himachal Pradesh, India. In Bangladesh, bandicoot rats cached up to 18 kg of wheat in one burrow system (Poché *et al*., 1982). In west Bengal, bandicoot rats accumulated 50 g to 4 kg of rice in burrows (Chakraborty, 1977). Fulk (1977) estimated that bandicoot rat populations stored 127 kg ha^{-1} beans in bean fields and 93 kg ha^{-1} rice in burrows in rice fields of Sindh, Pakistan. Recently, Maqbool *et al*. (2011) estimated a yield loss of 141.5 kg ha^{-1} in wheat fields of Muzaffarabad, Azad Jammu & Kahsmir (AJ&K). Unlike the above mentioned areas, the Pothwar plateau is characterized by a dry land agricultural system with low rainfall (Oweis amd Ashraf, 2012; Rashid and Rasul, 2011) and low soil organic matter (Latif *et al*., 2008; Mahmood *et al*., 2010; Rashid *et al*., 2008). Due to paucity of water, poor soil quality and the small size of land holdings, the agricultural productivity of this area is low. The losses due to rodent pests (mainly the bandicoot rat) therefore have a serious impact on the income of the resource poor farmers (Fulk *et al*., 1980a; Brooks *et al*., 1988; Khan *et al*., 2009). The objective of present study was to describe the burrow characteristics and hoarding habit of the bandicoot rat in the Pothwar agro-ecology

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and to use this knowledge in devising a strategy for integrated management of this rodent pest.

MATERIALS AND METHODS

Study area

The study area comprised the rainfed cropland of Chakwal (32° 33′ 0″ N, 72° 30′ 36″ E), a central district of Pothwar plateau, Pakistan. Climate of the area is semi-arid warm to hot with subtropical winter and monsoon with average annual rainfall ranging from 630 mm to 708 mm (Oweis and Ashraf, 2012; Rashid and Rasul, 2011). The mean annual temperature range is 23.5-30.0°C with highest daily temperatures (40.0-42.0°C) in June and lowest (2.2-4.7°C) in January (Beg *et al*., 1985). The soils have low organic matter and are a sandy loam to loam in texture; they are moderately calcaeous with an average pH value of about 8 (Sultan and Nasir, 2007; Mahmood *et al*., 2010; Khalid *et al*., 2012). The cropping system consists of wheat as the major winter crop (November-May) with inter-cropping of grams (chickpeas), lentils and mustards, while the summer crops (May-October) includes groundnut, sorghum and millet (Beg *et al*., 1985; Ahmad, 1990). The fields vary in size from 0.2 to1.0 hectare (Hussain and Prescott, 2006), and have thick undisturbed boundaries maintained to conserve water. The wild non-crop vegetation growing on the field boundaries comprises *Zizyphus nammularia, Capparia aphylla, Calotropis procera, Saccharum munja, Cynodon dactylon, Eragrostis cymosuroides, Desmostochya bipinnata* and *Sorghum halepense*. These provide shelter and food to rodents during the non-crop periods and the early crop growth stages (Hussain *et al*., 2003).

Plan of work

The study was conducted from September 2010 to June 2011 in crops of sorghum, groundnut and wheat at maturity and on crop field boundaries during the non-crop summer season in four villages of district Chakwal *i.e.* i) Chak Umra (32°58′N 72°57′E), ii) Chakora (32°47'N 72°43'E), iii) Mangwal (33°06'N 72°49'E), iv) Lakhwal (33°01'N 72°45'E).

Burrow systems from within the crop fields and on crop field boundaries were randomly selected for excavation. Lesser bandicoot rat burrows were identified by examining the size of burrow openings, excavated soil particles, presence of fecal droppings (size and shape) or foot tracks.

Before excavation, the number of surface openings of each burrow system was recorded. An opening with fresh soil mounds, foot tracks, fecal matter or cut plant material was considered active and used as the starting point for burrow excavation. The burrows were dug out carefully with hand tools to keep the tunnel system, food and nesting chambers and the stored materials intact. Attributes of the burrow systems we measured and recorded included; number of burrow openings, diameter of burrow opening; depth, length and diameter of main tunnel. Tunnel depth and diameter were recorded at intervals of about 30 cm along the tunnel. Some burrow systems were mapped in detail. Burrow chambers were identified by the presence of grasses and food materials. The hoarded material was recovered, and packed in plastic bags bearing field-related standard information. Burrow contents were subsequently separated in to food (crop seeds) and non-food (cut stems and leaves of cultivated and wild vegetation). Only crop panicles and seed parts were used to calculate the weight of stored/hoarded food. These contents were first air dried and then oven dried at 60°C for 24 h to constant weight. Values given in the text are means with their standard error ($\bar{x}$±SE). Comparison of parameters of the burrow systems excavated in different crop fields was made by One-way ANOVA and Fishers method was used for pair-wise comparison of the means, using the computer software MINTAB 16.

RESULTS

Parameters of the 30 excavated burrow systems are given in Table I. Representative sketches of the burrows from each habitat type are shown in Figure 1.

The eight burrows excavated in mature sorghum crops at maturity in September and October 2010 had 2.4±0.3 openings with mean diameter of 8.6±0.4 cm. Mean length and diameter of the main tunnel were 4.4±0.2 m and 8.9±0.2 cm, respectively. The burrows were 15.2±1.4 cm deep and had 1.8±0.4 chambers. The dry weight of the hoarded material recovered was 14.4±1.1 g per burrow system, which included crop stems and flower heads/seed parts.

The eight burrow systems excavated in mature groundnut crops in November 2010 were mostly in the low lying parts of the fields with higher soil moisture content and better crop cover. The mean number of openings per burrow system was 2±0.3 with diameter of 10.6±0.4 cm. The burrows' main tunnel was 3.5±0.2 m long, 11.1±0.7 cm deep and their diameter was 10.3±10.4 cm. Dry weight of the hoarded material found in six out of eight burrows was 18.7±0.7 g per burrow system.

The five active burrows excavated in wheat crop at harvesting in April 2011 were generally associated with areas of better crop stand. These burrow systems had 2.8±0.4 openings with mean diameter of 8.2±0.7 cm. Mean length of the burrow tunnel was 2.1±0.3 m with

diameter of 8.2±0.7 cm. Mean depth of burrows' main tunnel was recorded 14.5±1.8 cm. There were 2.0±0.3 number chambers per burrow system. We measured 10.5±3.4 g of crop straws and grain filled panicles stored per burrow system.

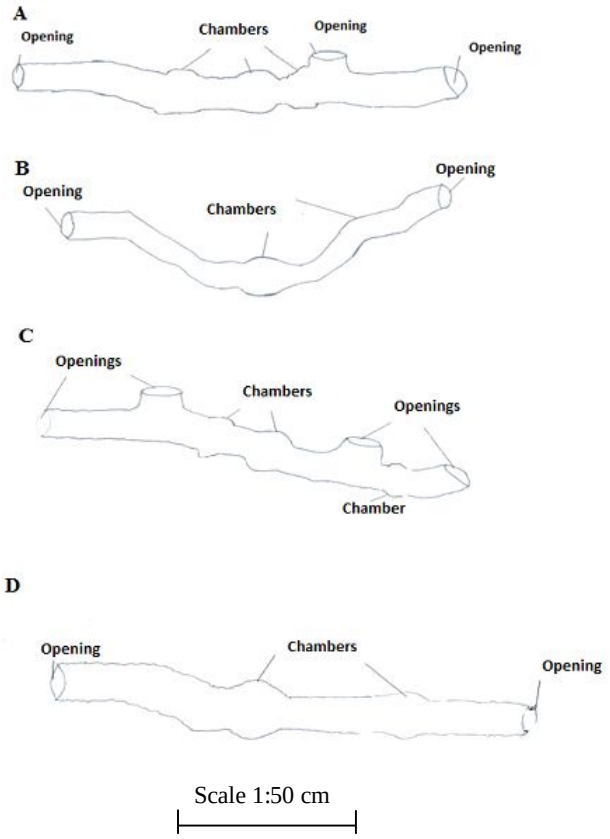

Fig. 1. Representative sketches of the lesser bandicoot rat (*Bandicota bengalensis*) burrows excavated in groundnut (A), sorghum (B), wheat (C) crops and crop field boundaries (D) in agro-ecosystem of district Chakwal of Pothwar plateau, Pakistan.

The nine burrow systems excavated from randomly selected crop field boundaries during the non-crop summer months (May-June) of 2011 were all found under wild vegetation of shrubs and grasses. The mean number of openings per burrow system was 1.6±0.2 with diameter of 7.4±0.4 cm. Mean length of the burrow tunnel was 4.9±0.6 m with a diameter of 7.6±0.4 cm. Depth of burrows was 7.0±0.3 cm. There were 1.7±0.2 number of chambers per burrow system containing scattered pieces of a common grass, *Cynodon dactylon*; these were not collected and weighed.

The size and numbers of openings of crop field boundary burrows were less than those of burrows in the fields of sorghum, wheat and groundnut crops (Table I). The diameter of main tunnel was greatest in groundnut crop, of almost equal size in wheat and sorghum crops and smallest in field boundary burrows. The main tunnels of field boundary and sorghum crop burrows were longer than those in groundnut and wheat crops. The burrows in wheat and sorghum crops were deeper than in groundnut crops, while shallowest in field boundaries. Numbers of chambers were similar regardless of crop type. The amount of stored food was highest in groundnut crops, followed by sorghum and wheat crops.

DISCUSSION

The lesser bandicoot rat is considered one of the most destructive rodent pests in croplands of central and northern Punjab, lower Sindh and AJ&K areas of Pakistan (Fulk *et al*., 1980a,b; Brooks *et al*., 1988; Siddique and Arshad, 2003; Hussain *et al*., 2003; Rana *et al*., 2006; Khan *et al*., 2009; Maqbool *et al*., 2011). Beside other demographic attributes, investigations on burrow characteristics and hoarding behavior of this rodent have been reported only from rice crops of lower Sindh (Fulk, 1977; Fulk *et al*., 1981) and wheat crops of AJ & K (Maqbool *et al*., 2011). Both of these locations are at extreme limits of the bandicoot rat distribution in Pakistan, and are primarily in rice-wheat cropping systems. Outside Pakistan burrowing and hoarding by bandicoot rats have been reported from many habitats in India and Bangladesh, and these studies are summarized in Table II. These data demonstrate variations in many characteristics of burrow systems, presumably related to the nature of crops, seasons, soil and its moisture content. Burrow systems recorded in the current study are of simpler design than all others recorded to date in the distribution range of *B. bengalensis* in Indian sub-continent.

The dimensions of the burrow systems measured in current study are markedly less than those reported in earlier studies (Table II). Such variations in burrow structures have been related to physical properties (Reichman and Smith, 1990) and texture of the soil (Shenbrot *et al*., 1997). In the croplands of the Pothwar plateau there is seasonal shift in the rodent population between cultivated crops and non-crop areas (mainly field boundary vegetation) (Hussain *et al*., 2003). Bandicoot populations are therefore residing in the crop fields only for 3-4 months. This periodic/seasonal movement of rats may not allow enough time for the species to construct deep and complicated burrow systems, compared to other environments (Armitage, 2003; Fitch, 1948; Reichman and Smith, 1990; Smith and

Table I.- Characteristics of the lesser bandicoot rat (*Bandicoota bengalensis*) burrows excavated in croplands of district Chakwal, Pothwar plateau, Pakistan.

S. No	Location/ Village	Burrow openings (n)	Diameter of burrow opening (cm)	Diameter of main tunnel (cm)	Length of main tunnel (m)	Depth of main tunnel (cm)	Burrow chambers (n)	Dry weight of hoarded material (g)	Nature of hoarded materials
Sorghum (at maturity stage; September-October 2010)									
1	Chakora	2	6.5	8	4	20	1	10	Leaves
2	Mangwal	2	8	9.1	4.8	19.5	1	12.5	Leaves
3	Chak Umra	3	10	10	3.6	18	1	14	Leaves
4	Chakora	4	9	9.4	5	12.5	2	13.5	flower heads and seeds
5	Mangwal	2	8.5	9	5.2	10.9	2	19	flower heads and seeds
6	Mangwal	2	8.5	9	5.2	10.9	1	19	flower heads, seeds and leaves
7	Lakhwal	2	9.2	8.5	4.2	11	4	13	Leaves
8	Mangwal	2	9	8	3.5	19	2	13.8	flower heads and seeds
Groundnut (at maturity stage; November 2010)									
1	Mangwal	2	7.5	10	4	12	1	--	--
2	Chakora	3	10	12.5	2	9.5	2	--	--
3	Mangwal	3	9	8.5	3.5	15.4	3	20.6	Peanuts
4	Lakhwal	2	8	10.5	4	11.5	1	20	Peanuts
5	Mangwal	2	8.3	10.3	3.8	11	1	19	Peanuts
6	Mangwal	1	10	12	3	9	1	18.5	Peanuts
7	Lakhwal	2	9	11	3.5	10	2	19	Peanuts
8	Mangwal	1	9.8	10	4	10	2	15	Peanuts
Wheat (at maturity stage; April 2011)									
1	Lakhwal	3	9	9.8	2.5	13	2	3.8	panicles, straws
2	Lakhwal	4	10.5	10	3	10	3	4	Panicles
3	Lakhwal	2	8.5	8	1	15.9	1	14.6	Grains
4	Chak Umra	3	6	6.8	1.9	13.2	2	8.3	panicles, straws
5	Lakhwal	2	9.9	6.5	2	20.6	2	21.7	Grains
Boundaries of uncultivated fields (May-June 2011)									
1	Lakhwal	2	6.4	7	3.5	6.8	2	--	Cuttings of *Cynodon dactylon* scattered in burrow chambers. (not collected and weighed).
2	Mangwal	1	8	9	7.5	8.2	2	--	
3	Mangwal	1	5	5	3	6	2	--	
4	Lakhwal	2	8	8.2	4	5.9	1	--	
5	Mangwal	1	7.8	8	3.8	7	2	--	
6	Mangwal	2	7.5	7.5	4	7.5	2	--	
7	Mangwal	2	7	8	4.5	8	1	--	
8	Lakhwal	1	6.8	8	6.5	6.5	1	--	
9	Lakhwal	2	8	7.8	7	7.2	2	--	
Sorghum ($\bar{x}$±SE)		2.4 ± 0.3^{A}	8.6 ± 0.4^{A}	8.9 ± 0.2^{B}	4.4 ± 0.2^{AB}	15.2 ± 1.5^{A}	1.8 ± 0.4^{A}	14.4 ± 1.1^{AB}	
Groundnut ($\bar{x}$±SE)		2.0 ± 0.3^{AB}	9.0 ± 0.3^{A}	10.6 ± 0.4^{A}	3.5 ± 0.2^{B}	11.1 ± 0.7^{B}	1.6 ± 0.3^{A}	18.7 ± 0.7^{A}	
Wheat ($\bar{x}$±SE)		2.8 ± 0.4^{A}	8.8 ± 0.8^{A}	8.2 ± 0.7^{BC}	2.1 ± 0.3^{C}	14.5 ± 1.8^{A}	2.0 ± 0.3^{A}	10.5 ± 3.4^{B}	
Field Boundaries ($\bar{x}$±SE)		1.6 ± 0.2^{B}	7.2 ± 0.3^{B}	7.6 ± 0.4^{C}	4.9 ± 0.6^{A}	7.0 ± 0.3^{C}	1.7 ± 0.2^{A}	--	
All		2.1±0.1	8.3 ±0.2	8.8±0.3	3.9±0.3	11.5±0.8	1.7±0.1	14.7±1.2	

Means that do not share a letter (column-wise) are significantly different.

Table II.- Burrow characteristics and food hoardings of lesser bandicoot rat (*Bandicota bengalensis*) in different ecologies of Indian subcontinent.

S. No	Habitat and location	Burrow length (m)	Diameter of burrow opening (cm)	Burrow depth (cm)	No. of burrow openings (n)	No. of burrow chambers (n)	Quantity of hoarded food (kg)	Reference
1	Rice, west Bengal	4.3-45	--	3-10	1-16	--	3.2 (0.05-4)	Chakraborty, 1977
2	Rice, Sindh, Pakistan	--	--	pulses seed cache depth: 38 (15-52)	--	--	Pulse: 0.753 Rice: 0.920	Fulk, 1977
3	Punjab, India	--	11.5-12.3	71-87	10-14	Food: 1-4 Nest: 1-3	--	Chanda and Garg, 1981
4	Wheat, Bangladesh	40.2 (33-55)	7.69 (6-10)	16.7 (6.5-24)	6.4 (1-16)	Food: 2.5 (0-7) Nest: 1.6 (0-4)	2.1 (0-18)	Poché *et al*., 1982
5	Garhwal-Himalyas, India	≤ 20.3	--	--	--	--	0.3	Sheikher and Malhi, 1983
6	Deep water rice, Bangladesh	9.4 (1.3-27)	--	--	7 (1-17)	--	--	Ahmed *et al*., 1986b
7	Wheat, Himachal Pradesh, India	--	--	--	--	--	0.486	Sheiker and Jain, 1991
8	Utter Pradesh, India	5.018	7.6	62.2 Winter: 40.3 Summer: 80.2	5.4	Food: 3.1 Nest: 1.3	0.285	Bhaduria and Mathur, 1993
9	Tamil Nadu, India	--	--	--	1-3	--	--	Sivaprakasam and Durairaj, 1995
10	Field crops, Utter Pradesh, India	--	--	Sugarcane: 18.4 Wheat: 15.4	Rice and Wheat: 13.4 Sugarcane: 6.0	Wheat: 2.4 Peas: 1.6	Wheat: 1.27 Sugarcane: 0.11	Rajak *et al*., 2000
11	Crops, Himachal Pradesh, India	--	--	Wheat: 18.5 Peas: 18.8	Wheat: 17.1 Rice: 11.3	--	Wheat: 0.926 Peas: 0.162	Sood and Chand, 2007
12	Wheat, AJ&K, Pakistan	4.13 (1.8-5.5)	8.9 (8.6-9.1)	14.3 (9.7-21.6)	2.3 (1-3)	2.5 (1-5)	0.478 (0.2-2.6)	Maqbool *et al*., 2011
13	Pothwar cropland (rain-fed), Punjab, Pakistan	3.9 (1-7.5)	8.3 (5-10.5)	11.5 (6-20.6)	2.1 (1-4)	1.7 (1-4)	0.015 (0.004-0.021)	Present study

Gardner, 1985) where burrows are occupied for an extended period and may become progressively longer and deeper. For example, newly excavated burrows of Gunnison's prairie dogs often are shorter than established burrows (Longhurst, 1944). The soil texture and low organic matter of the soils at Chakwal may also make burrow excavation more costly (Reichman and Smith, 1990; Kwiecinski, 1998).

Burrows on field boundaries were smaller and shallower than those in the crop fields. The bandicoot rats inhabit crop field boundaries during the non-crop or early growth periods of the winter (wheat) and summer (sorghum and groundnut) crops (Hussain *et al*., 2003). During non crop seasons the species either ceases breeding (December-January) or significantly reduces this activity (May-June) so that nesting chambers may not be needed in the burrows (Hussain *et al*., 1992, 2002). The relatively shallow burrows in crop boundaries during the period of above ground food scarcity suggests the feeding of rats may focus on rhizomes and roots of grasses and other wild vegetation at that time (Hussain *et al*., 1994). Possibly also animals living inside the crop fields may have had a good supply of food and cover and so did not need to spend much time in excavating longer burrow systems to increase protection. Moreover, frequent surfacing for food under the protective cover of crops could have resulted in more frequent larger burrow openings in the croplands.

The new information about the characteristics of bandicoot rat burrows in Pothwar agro-ecosystem suggests practical opportunities for improving control of this rodent pest. 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 other predators. The small number of burrow openings will facilitate the identification of active burrow openings for the application of rodenticide baits or rodent traps. However, the shallow nature of the burrow systems may preclude application of fumigants for rat control. Future research should explore the relationship between burrow attributes and soil structure, texture and moisture contents; availability of food and cover; and the life cycle phases of the rodent species.

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