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Correlation of abiotic factors with burrow dimensions of Indian gerbil, *Tatera indica* in sandy-loam soil at different seasons of Punjab

Abha Sharma and Rajwinder Singh

Abstract
Indian economy largely depend on agriculture for its success which is retarded by many pests. Rodents are major vertebrate pests of agricultural crops during pre-and post-harvest stages. In our study fresh burrows of *Tatera indica* were excavated from sandy-loam soil from village Ladhowaal, District Ludhiana, at monthly intervals. The months were divided into five seasons. *T. indica* makes burrows with different parameters as the weather changes from summer to winter seasons. *T. indica* dig burrows with depth of 71.45cm when soil temperature and soil moisture recorded were 34.81^{0}C and 13.72% (mean), respectively during summer season, and length of 226.18cm when mean soil temperature and soil moisture observed were 15.32^{0}C and 24.44%, respectively in winter season. In sandy-loam soil, length of burrow is negatively correlated with soil temperature (-0.977) and positively correlated with soil moisture content (+0.611), whereas depth of burrow is positively correlated with soil temperature (+0.935) and negatively correlated with soil moisture content (-0.696). *T. indica* make burrows in sandy-loam soil due to having more sand content, electrical conductivity and bulk density. The burrows were characterized with single or multiple openings having mean number of open and blind ends ranged from 1.42 to 2.84 and 1.21 to 1.98, respectively. Present study is useful for the management of rodents in crop fields i.e., by placing poison baits in burrows, to reduce rodent damage.

Keywords: *Tatera indica*, burrow structure, excavation, Indian gerbil

Introduction

Rodents constitute the largest and most ancient group of mammals of which 40% belong to order 'Rodentia' (Young, 1962) [39] due to their small size, short breeding cycle and ability to gnaw, eat a wide variety of foods, cosmopolitan in distribution and have the ability to adapt to a wide variety of habitats (Jacob and Cox, 1977) [12]. *Tatera indica* popularly known as Indian gerbil is a nocturnal mammal which lives in farm fields as individual and causes damage to agricultural crops (Kam *et al*., 1997; Vaughn *et al*., 2000) [14, 36]. Worldwide it is dispersed in Iran, Afganistan, Kuwait, Syria, India, Pakistan, Sri Lanka and Nepal (Khajeh and Meshkani 2010; Alderton 1996; Wilson and Reader 1993) [17, 1, 38]. It is more widely adopted in sandy soil than others (Goyal and Ghosh 1993) [9]. These live in underground by making burrows having shapes of "Y" or "V" shape, complex network of tunnels and the dimensions/densities of burrows vary with change in season, topography, soil quality and habitat (Vaughn *et al.*, 2000; Kocher and Parsad, 2003; Porter *et al.*, 2002; Begall and Gallardo, 2000; Kam *et al.*, 1997; Parmesh and Pasahan 1993) [36, 19, 27, 3, 14, 26]. Various studies have been conducted on burrow densities of rodents in relation to abiotic factors (Malhi and Sheikhar 1984) [23]. Taxonomically *T. indica* belong to order "Rodentia" and family "Muridae', which constitutes 41.6% of rodents found in the sandy biome (Prakash, 1975) [28]. The burrows are used for different activities like nesting, food storage, hibernating and shelter (Reichnnan and Smith, 1987; Kinlaw, 1999; Stone and Comerford, 1994; Butler, 1995) [32, 18, 34, 2]. Various biotic parameters (Johnson *et al.*, 2001; Clark *et al.*, 2002) [13, 5] and physical characteristics of soil (Romanach, 2003) [33] also affect the burrowing activity of rodents. Knowledge of burrowing habit of rodents is required to study their social organization, behaviour of dominance (Prakash and Mathur, 1987) [29], population estimation and placing poison baits in burrows to control them (Neelanarayanan *et al.*, 1996) [24]. In the present study, some efforts have been made to get knowledge about burrow structure by excavating the fresh burrows of *T. indica* under different seasons in sandy-loam soil of Punjab. Our study will help in the formation of policies which include strategies for rodent pest management to reduce food grain damage from rodents.

Materials and Methods

Selection of site: Our study was carried out in the fields of village Ladhowaal, having sandy-loam soil District Ludhiana (Punjab) and laboratory experiments were carried out in the

Departments of Zoology and Soil Science, Punjab Agricultural University, Ludhiana. The farmers prefer to grow crops like maize, paddy, wheat, vegetables like radish, cabbage, spinach, carrot, lady finger, cucurbits and fodder crops. During study, in both soils 20 to 25 burrows were excavated per month and each burrow was 1-2 day old.

Selection of seasons: The study was done on monthly basis so, the months were grouped into different seasons like winter (December to February), spring (March to April), post-monsoon (September to November), monsoon (July and August) and summer (May and June) depending upon weather conditions. During summer season, the site selected was harvested fields of wheat crop, similarly paddy crops in monsoon season, around paddy and maize crops in post-monsoon and around wheat fields during winter and spring seasons.

Determination of burrow parameters: Excavation was done with the help of spade and khurpa. Burrow parameters recorded during excavation were length/breadth of open ends (cm), count of open/blind ends, branches, number of nest chambers, length/breadth of nest chambers, weight of hoarded food, number of rats captured. Measuring tape was used to record all the above parameters.

Determination of soil parameters: Soil samples from excavated burrows were collected at different depths from zero, one and two feet. Soil was examined by recording soil temperature, soil moisture, electrical conductivity (EC), soil texture, soil pH, bulk density (D_b), particle density (D_p) and organic carbon (OC). Before taking soil sample surface litter was removed thoroughly. Soil samples were taken out separately with spade and packed in cloth bags. Soil texture was determined by feel method, ball formation, stickiness, ribbon formation methods as suggested by Mehra, (2014) [21]. Soil moisture content was determined by using Gravimetric method (Prihar and Sandhu, 1968) [31]. Soil temperature at varied depths (5, 10 and 30cm) was recorded by using digital soil thermometer (R-Tek ™ Shenzhen Tonglixing Technology Co., Ltd. China, Mainland). To measure pH, potentiometric method (Jackson 1967) [11] was used. Conductivity meter (Chopra and Kanwar, 1976) [4] was used for the determination of electrical conductivity of soils. Clod saturation method was used in which soil moisture gauge or pycnometer was used for the determination of bulk density of soils (Prihar and Hundal, 1971) [31]. PAU soil moisture gauge method was used for determining particle density of soils (Prihar and Sandhu, 1968) [31]. Organic carbon in soils was determined by wet digestion method (Walkley and Black, 1934) [37] rapid titration method.

Results and Discussion

Determination of soil parameters: The results regarding determination of different soil parameters are as under:

Soil textures: Feel method was used to distinguish soil type i.e., sandy-loam soil. This soil was found to be moderately gritty, so, ball was formed which easily get broken and length of ribbon formed was 1.92±0.12cm which shows its medium textured nature. Earlier in a study Mehra (2014) [21] also recorded length of ribbon formed in the range from 1.5 to 2.0cm in sandy-loam soil.

Soil pH: Our results showed that as the depth of soil increases the pH value of soil also increases. Mean soil pH values recorded in sandy-loam soil, was 8.10±0.08, 8.20±0.12, 8.25±0.12 at varying soil depths 0, 1 and 2 feet (Table 1).

Soil electrical conductivity (EC): Electrical conductivity (dS/m) of soil decreases with increase in depth. EC value of sandy-loam soil at different depths of 0, 1 and 2 feet recorded ranged from 0.081±0.016 to 0.110±0.014.

Soil bulk density: Bulk density (D_b) (Mg m^{-3}) of soil increases with increase in depth. The mean bulk density of sandy-loam soil at depths 0, 1 and 2 feet ranged from 1.35±0.03 to 1.42±0.06 (Table 1).

Soil particle density: Our results revealed that particle density (D_p) (Mg m^{-3}) of sandy-loam soil at varying depths ranged from 2.70±0.01 to 2.73±0.01. So, as the depth of soil increases its particle density also increases.

Soil organic carbon (OC): Organic carbon of sandy-loam soil ranged from 0.299±0.08 to 0.340±0.09 (Table 1). So, it is concluded that organic carbon decreases with increase in soil depth. Bulk density and particle density of sandy-loam soil increases with depth due to low organic carbon and more sand content which lead to less soil porosity resulting increase in water infiltration rate and decrease in water holding capacity that provide suitable condition for burrowing activity of rodents.

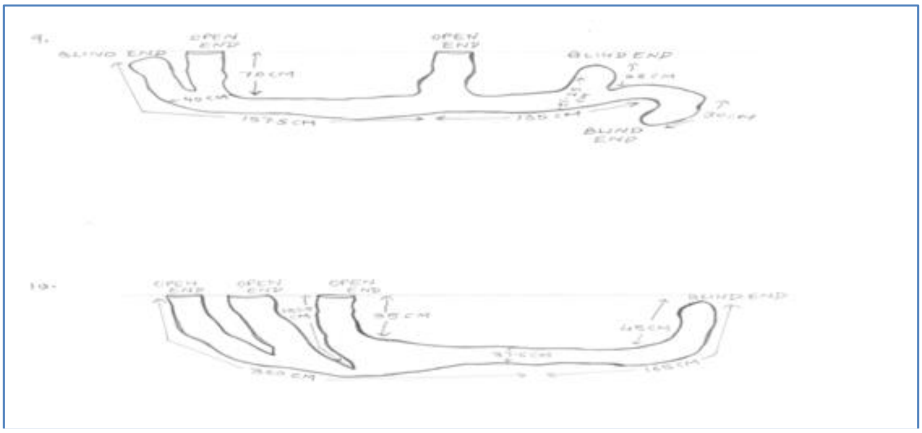
Soil moisture content (%): In sandy-loam soil there was a great shift of the change in moisture content of the soil. The per cent moisture content of soil ranges from 13.72±0.54 to 25.62±0.36 during all the seasons (Table 2).

Soil temperature (^{0}C): Soil temperature (^{0}C) decreases with increase in depth of soil. It ranged from 15.32±0.26 to 33.83±0.72 in sandy-loam soil. Soil temperature was recorded maximum to be in summer season and minimum during winter season (Table 3).

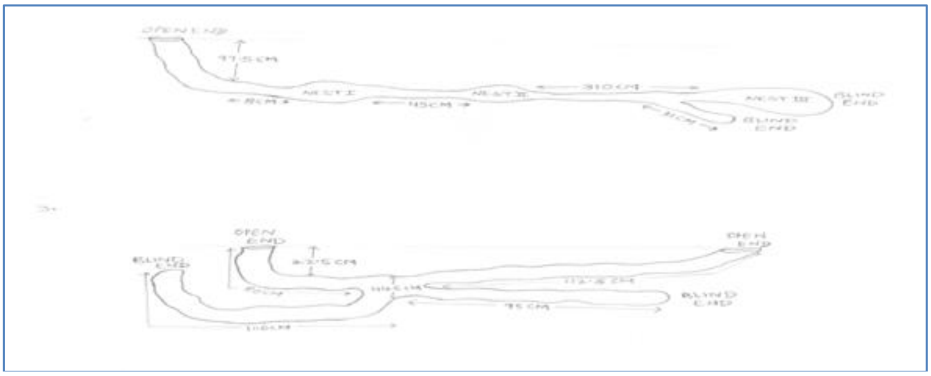
Burrow parameters: While excavating burrows at different times, the burrow parameters recorded are as under:

Length/depth of burrow: Burrows of *T. indica* has single or multiple openings and it follow Y or V shaped pattern. The main entrance of burrow run deep like slanting tunnel. In sandy-loam soil, lower length (171.08±3.10cm) of burrow was recorded in summer whereas higher (226.18±3.74cm) in winter season (Table 4). The increase in burrow length was higher during winter, which declines in spring season. Similar variation was observed in recording depth during different seasons. Maximum depth (71.45±2.21cm) was observed in summer, whereas minimum (47.51±2.36cm) during winter. Interestingly, depth of burrows was higher during summer season, which then reduces in winter season. From our results, we have come to the conclusion that in winter season, formation of length is maximum and depth is minimum, whereas maximum depth and minimum length was observed during summer season, because of high temperature during summer season, whereas low in winter. So, to have congenial environmental conditions for living in burrow, rat decreases the length and increases the depth of burrow during summer season and vice versa during winter season (Sketch 1 and Sketch 2). Different depths of kangaroo rat (Kenagy and

Smith, 1973) [15]; chisel toothed kangaroo rat (Kenagy and Smith, 1973) [15]; pocket gopher (Kennerley, 1964) [16]; karroo rat (Graaf and Nel, 1965) [10], Cape short-eared gerbil (Nel, 1967); white throated wood rat (Kenagy and Smith, 1973) [15]; little pocket mouse (Kenagy and Smith, 1973) [15] and desert gerbils in the range from 20-70cm. Mean burrow length of 159.0cm in sandy soil and 129.30cm in loamy soil was recorded in *B. bengalensis* burrow (Kocher and Parsad, 2003) [19].



Sketch 1: *T. indica* burrows during summer and spring seasons



Sketch 2: *T. indica* burrows during winter season

Table 1: Different soil parameters at various depths of sandy-loam soil

S. no.	Depth (feet)	Soil pH	Electrical conductivity (EC) (dS/m)	Organic carbon (OC) (%)	Bulk density (D_b) (Mg m^{-3})	Particle density (D_p) (Mg m^{-3})
1	0	8.10±0.08	0.110±0.014	0.340±0.09	1.35±0.03	2.68±0.01
2	1	8.20±0.12	0.090±0.010	0.337±0.08	1.39±0.04	2.71±0.09
3	2	8.25±0.12	0.081±0.016	0.299±0.08	1.42±0.06	2.73±0.01

Table 2: Moisture content (%) of excavated *T. indica* burrows in sandy-loam soil during different seasons at varied depths

S. no.	Seasons	Depth (feet)	Sandy-loam soil
1	Summer	0	12.50±1.65
		1	13.85±0.72
		2	14.81±0.50
		Average	13.72^d±0.54
2	Monsoon	0	24.75±1.25
		1	25.91±1.12
		2	26.20±10.31
		Average	25.62^d±0.36
3	Post-monsoon	0	17.33±1.10
		1	24.45±0.72
		2	25.12±0.92
		Average	22.30^d±2.03
4	Winter	0	22.13±0.51
		1	25.02±0.42
		2	26.17±1.31
		Average	24.44^d±0.97
5	Spring	0	16.56±1.14
		1	18.43±1.12
		2	23.90±0.72
		Average	19.63^d±1.79

Table 3: Soil temperature (^{0}C) in excavated *T. indica* burrows in sandy-loam soil during different seasons at varied depths

Seasons	Soil depths		
	5cm	10cm	30cm
Summer	35.50±0.4 0	33.5±0.51	32.5±0.72
Monsoon	32.40±0.10	32.70±0.14	29.50±0.31
Post-monsoon	26.10±2.12	24.50±3.72	23.50±3.50
Winter	14.80±2.08	15.24±0.72	15.92±0.65
Spring	24.50±1.82	23.50±2.73	22.50±2.14

Table 4: Length/depth of burrow and its open ends, number of branches, open and blind ends of excavated *T. indica* burrows in sandy-loam soil during different seasons

S. no.	Seasons	Burrow length (cm)	Burrow depth (cm)	Length of open ends (cm)	Breadth of open ends (cm)	Number of branches	Number of open ends	Number of blind ends
1	Summer	171.08±3.1	71.45±2.2	7.46±0.61	6.02±0.72	2.84±0.03	1.53±0.21	1.46±0.25
2	Monsoon	187.56±2.9	61.54±1.9	7.50±0.46	7.92±0.20	3.78±0.03	2.84±0.18	1.98±0.46
3	Post-monsoon	195.32±3.1	53.20±2.2	7.75±0.08	7.88±0.51	3.16±0.19	2.35±0.21	1.78±0.48
4	Winter	226.18±3.7	47.51±2.3	7.80±0.31	8.01±0.31	1.52±0.19	1.42±0.16	1.21±0.10
5	Spring	203.06±2.1	55.45±2.5	8.10±0.11	10.21±1.12	3.49±0.02	2.01±0.20	1.52±0.31

Relation of soil moisture content and soil temperature with length and depth of burrow: The maximum mean soil temperature was recorded during summer season (33.83±0.72cm) due to high atmospheric temperature while minimum during winter (15.32±0.26cm) due to low atmospheric temperature in sandy-loam soil. Maximum per cent soil moisture (25.62±0.36cm) was recorded in monsoon, while minimum (13.72±0.54cm) was recorded during summer. During summer there was a high atmospheric and soil temperature which tends to increase evaporation rate.

In sandy-loam soil, T. indica dig burrows deep (71.45±2.21cm) in summer, when soil moisture was 13.72±0.54% and soil temperature around 34.81±0.61^{0}C. Due to fluctuations of atmospheric and soil temperatures and soil moisture as the seasons changes from winter to spring, length of burrow increases whereas depth decreases. Similarly, during winter, when mean soil temperature recorded was 15.32±0.26^{0}C and soil moisture 24.44±0.97%, the mean length of burrow recorded was 226.18±3.74cm. In sandy-loam soil, length of burrow is negatively correlated with soil temperature (-0.977) and positively correlated with soil moisture content (+0.611), whereas depth of burrow is positively correlated with soil temperature (+0.935) and negatively correlated with soil moisture content (-0.696). As per evaluating data in linear model, we got the equations for calculating the relationship between length, depth, soil temperature and soil moisture for sandy-loam soil.

In sandy-loam soil, the equation derived is:

Length = 243.352 - 2.468 × soil temperature + 0.799 × soil moisture

Depth = 45.843 + 0.974 × soil temperature + 0.621 × soil moisture

This model was statistically significant with R^2 value of 0.95 for sandy-loam soil, where R^2 is coefficient of determination.

Soil texture is a primary factor which limits the distribution of some fossorial mammals (Miller, 1964) [22]. Pocket gophers make burrows having more depth in dry soil (Crouch, 1933) [7]. In areas where there is more rainfall there is increase in soil moisture content, which increases ease of burrow digging as compared to dry soils (Collis-George, 1959, Ghobrial and Nour, 1975, Kucheruk, 1983) [6, 8, 20].

Number of branches, open/blind ends and their dimensions: In loamy-sand soil during different seasons, the number of branches of excavated burrows ranged from 1.52±0.19 to 3.78±0.03. It was observed that numbers of blind ends were found to be lowest during winter and highest in monsoon season. The number of open ends of burrows ranges from 1.42±0.16 to 2.84±0.18 (Table 4). Similarly, mean number of blind ends ranged from 1.21±0.10 to 1.98±0.46 during selected seasons in sandy-loam soil. Higher number of open and blind ends was recorded during monsoon and lowest during winter seasons, due to more food availability and population build up of T. indica. Length and breadth of open ends of burrows ranged from 7.46±0.61 to 8.10±0.11 and 6.02±0.72 to 10.21±1.12, respectively. Statistically there was non-significant difference between the values. In a study by Kocher and Parsad, (2003) [19] they recorded six burrow branches in sandy soil and two in loamy soil. Other researchers like Ubi, (1975) [35]; Malhi and Sheikhar, (1984) [23] recorded the number of open ends of B. bengalensis burrows ranging from 2-10, M. booduga 1-3, T. indica 1-3 in both sandy and loamy soils. The diameter of open ends varied among B. bengalensis (4.4-10.4cm), M. booduga (2.2-3.4cm) and T. indica (3.5-8.3cm).

Nest chambers and their dimensions: Number of nest chambers of burrows ranged from 1.23±0.12 to 1.84±0.20 during different seasons in sandy-loam soil. The mean area of burrow nest chambers during different seasons ranged from 762.85±81.62 to 1589.40±82.08 (Table 5). Only single adult was found in post-monsoon season. Ubi, (1975) [35]; Malhi and Sheikhar, (1984) [23] reported the number of food chambers in three species *B. bengalensis*, *T. indica* and *M. booduga* in tune of 2-14, 0-1 and 0-2, respectively, food hoarded by B. bengalensis, T. indica and M. booduga 0-3700g, 0-260g and 0-2500g, respectively and depth of brood chambers 45-97.5cm (B. bengalensis), 12.0-22.0cm (*M. booduga*) and 48.0-85.0cm (*T. indica*).

Table 5: Parameters of nest chambers of excavated *T. indica* burrows in sandy-loam soil during different seasons

S. no.	Seasons	No. of chambers	Length of nest chambers (cm)	Breadth of nest chambers (cm)	Area of nest chambers (cm)	Hoarding material	Number of rats recovered
1	Spring	1.48±0.09	38.50±5.62	32.50±1.92	1291.01±24.78	--	--
2	Summer	1.56±0.14	40.08±0.81	36.50±4.63	1589.40±82.08	--	--
3	Monsoon	1.84±0.20	30.25±2.94	28.65±2.25	1098.35±98.30	--	--
4	Post-monsoon	1.69±0.32	29.25±6.42	27.20±7.46	1184.21±24.70	--	Adult=1
5	Winter	1.23±0.12	24.85±5.50	23.12±5.4	762.85±81.62	--	--

Conclusion

Agriculture is threatened by rodents from pre-harvest to post-harvest stages of crops. It is observed that there is change in digging behavior of T. indica as the season changes from summer to winter in Indian conditions i.e., length, depth of soil, number of open and blind ends and nest chambers changes with respect to climatic change in season. T. indica dig burrows in sandy-loam soil due to having more sand content, electrical conductivity and bulk density. Our study may help in basic research and development of policies that include strategies for rodent pest management i.e., placing poison baits in burrows to reduce rodent damage to food grains which will help in food security of nation.

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