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Dietary Habits of Indian Gerbil *Tatera indica* Inhabiting Agro-Ecosystem of Pothwar Plateau, Pakistan

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ABSTRACT

The Indian gerbil *Tatera indica* occurs in the Pothwar Plateau and is associated with agro-ecosystem of the area. No particular scientific studies have been focussed on dietary habits of this species in particular Plateau. Therefore, the focal aim of the current study was to investigate the dietary habits of Indian gerbil by using micro-histological analysis of stomach contents in croplands of the Pothwar Plateau and to study the variation in its food composition during cropping and non-cropping seasons. A total of 30 specimens were trapped by using snap traps in wheat, groundnut and adjacent non-crop habitats. Results showed that the gerbil rat was chiefly omnivore; feeding on wheat-groundnut plants and grains as the crops approached maturity, wild flora (viz: herbs, grasses, seeds and tubers) invariably amongst crop stages and seasons. During spring season, wheat was the most frequently consumed cereal. But during winter, as groundnut crop approached towards maturity/harvested, gerbils consumed mainly nuts and grains, while in autumn and summer (non-crop periods), the rat species switched its diet to wild flora, and consumed most frequently *Ziziphus nummularia* (Beri) followed by *Cynodon dactylon* (Khabbal grass), *Desmostachya bipinnate* (Baron dhab), *Artemisia dubia* etc. along with some fodder crops like *Sorghum bicolour* (Sorghum), *Zea mays* (Maize), *Brassica campestris* (Mustard) etc. The summer diet (non-crop season) was comparatively less diversified than the diet of the cropping season (spring) and there was a significant difference in the diets of this rat species during cropping and non-cropping period. The gerbil also supplemented its diet with insects (animal matters) in higher quantities highlighting its positive role as biological control of insect pests of croplands. Analysis of Variance (ANOVA) later followed by Least Significance Difference (LSD) revealed significant differences during cropping season winter (wheat) and non-cropping season autumn ($F = 1.88$, $df = 18$, $P < 0.05$). The frequency of different food items of cropping and non-cropping season (summer and monsoon) showed the significant difference ($F = 1.15$, $df = 18$, $P < 0.05$) and the remaining unidentified food items were non-significant to each other ($F = 1.10$, $df = 18$, $P > 0.05$). The study concludes that Indian gerbil has got a beneficial role for sustainable agriculture practices.

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AR and TM designed the study. AR collected experimental research data and interpreted the results. AR, AS, AB, MF and NM assisted in experimental and statistical analysis. AR wrote up the research article. TM supervised and revised the Manuscript. All of the authors read and approved the manuscript.

Key words
Indian gerbil, Dietary habits, Stomach contents, Omnivore, Snap traps

INTRODUCTION

Rodents are the largest mammalian order (over 2000 species) and show incredible ecological diversity. The remarkable adaptability and opportunism that exemplify rodent feeding behaviours are evident in their diverse and versatile feeding apparatus. All rodents are characterized by a single pair each of chisel-like upper and lower incisors, which are both self-sharpening and ever-growing. Rodents use their incisors for many tasks, including gnawing, cutting down and damage crop plants/vegetation's, digging, and capturing prey. Some rodents are serious pests to agriculture and cause significant loss to crops and stored products. Their damage correlates to the crop growth stage and very low (0.5%) before booting stage and increases to 12.1% at the maturity stage (Sarwar, 2015). It is to mention that breeding pattern and population of rodents depends on food availability, cover and season (Munawar *et al*., 2018). Availability of food resources is one of the more important factors recognized to control small-mammal populations (Taitt and Krebs, 1981); these studies are of more than purely academic interest in agro-ecosystems where increasing populations of rodents can result in significant decreases in crop productivity and substantial economic losses.

Rodents have economical, ecological, communal and

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traditional significance and provide our environment with major benefits (Singleton *et al*., 2003). Most of the rodent species play a vital role in maintaining the ecosystem, that is, predator-prey relationship, pollination and seed dispersal and in maintaining ecological equilibrium and modification of habitat (Habtamu and Bekele, 2008). They also play a crucial role in nutrient cycling and water flows in many biomes. Indian gerbil *Tatera indica* constructs subterranean burrows through the soil, consuming above and below ground plant materials (Huntly and Inouye, 1988). Thus, burrowing activity of rodents is affected by both the physical characteristics of the soil and the availability of food (Romanach, 2003). The density of their burrows varies enormously between habitats and between seasons. Abiotic factors interact with each other in several complex ways to influence biotic factors.

Indian gerbil is reportedly omnivorous, and feeds upon natural wild vegetation/plants, grasses, herbs, shrubs, parts of standing crops and their roots, seeds and insects (Munawar *et al*., 2020). Hussain *et al*. (2003) reported that Indian gerbil burrows are found on the undisturbed field boundaries that had *Zizyphus nummularia* dominated vegetation. The species constructs underground burrows for series of activities such as trampling, wallowing, digging and geophagy that can have tremendous impacts on the landscape (Stone and Comerford, 1994; Butler, 1995). Its burrows are of simple patterns and easily identified by clear one or two surface openings (Munawar *et al*., 2018) which provide a stable micro-climate and protection from extreme temperatures and shelter from predators during their surface activity (King, 1984; Reichnnan and Smith 1987; Kinlaw, 1999).

The Indian gerbil occurs in the Pothwar Plateau and is associated with agro-ecosystem of the area. However, so far, no particular scientific studies have been focussed on dietary habits of this species in this particular Plateau. Therefore, the focal aim of the current study was to investigate the dietary habits of Indian gerbil by stomach contents analysis and to study the variation in its food composition during cropping and non-cropping seasons.

MATERIALS AND METHODS

Study area

The current study was carried out in the Pothwar Plateau, located in the north part of the Punjab province (Fig. 1). The study area has sub-tropical dry scrub vegetation and rich floral diversity. Trees and shrubs bearing specific characteristics of scrub forest are abundant in this area. *Vachellia modesta*, *Olea ferruginaea* and *Tecomella undulata* are important wild tree species while several shrubs and grasses are native to the Pothwar region, including the most abundant species of *Dodonaea viscosa*, *Justicia adhatoda*, *Maytenus royleanus, Ziziphus nummularia* (Beri), *Achyranthes aspera, Chrysopogon serrulatus*, *Heteropogon contortus*, *Dichanthium foveolatum*, *Cynodon dactylon* (Khaball grass) and *Aristida mutabilis* (Munawar *et al*., 2020). The total area of this region is 22,255 km^2 which includes four districts (Attock, 6,857 km^2; Chakwal, 6525 km^2; Jhelum, 3587 km^2; Rawalpindi, 5,286 km^2) and some parts of the Islamabad capital territory are also included (Mahmood *et al*., 2017). The Plateau lies at an altitude of 330 – 1,000 m above sea level and the climate is semi-arid to tropical, mean rainfall of 380–510 mm per annum (Mahmood *et al*., 2017). The mean average summer temperature is 45° C, dropping to below freezing in winter (Encyclopedia Britannica, 2010). The Pothwar cropping system comprises of uncultivated e.g., range land and dry scrub forest along with cultivated farmland, with dissected zone of undulating settings, valleys, low fertile lands and irregular precipitation, mostly in the months of July and August.

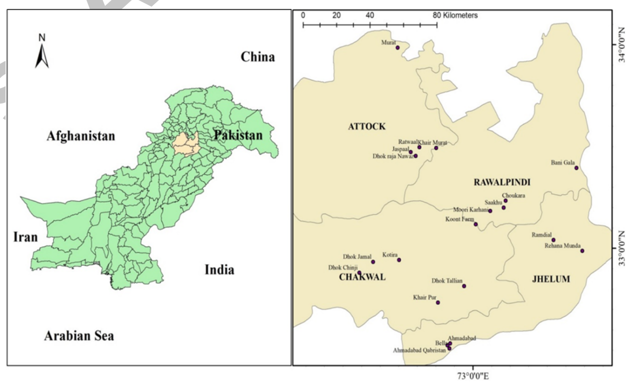

Fig. 1. Map of Pakistan, showing location of the Pothwar Plateau, where the study was conducted.

Study design and trapping methodology

Indian gerbil was trapped from September 2018 to July 2019 from agriculture areas of four selected study sites (one site from each district), that is, Attock, Chakwal, Jhelum and Rawalpindi of the Pothwar Plateau, using locally designed snap/kill traps. The anthropogenic activities in the study area were found widespread including agricultural practices, cattle farming, pasture fields for livestock and many of the linear habitats were removed to enlarge agricultural lands. Major habitat types selected include crops (primarily wheat, groundnut, millet and maize), post-harvested crop fields and the adjacent stable non-crop border habitats.

Trapping of Indian gerbil was carried out by using snap/kill traps baited with the most preferred food baits;

guava and peanut butter smeared on piece of chapatti (bread) due to their taste and smell (Munawar *et al*., 2019). At each sampling site, approximately 5.0 ha area of cropland with adequate inhabitants of gerbil rat burrows was selected during the harvested season and its growth period. The baited traps were placed near active burrows of the gerbil rats into the prevailing crop fields of wheat-groundnut for overnight. Some traps were also set under wild vegetation at the field borders. Forty snap traps were placed for three consecutive nights in such a way that it was never repeated in the same fields/areas during the course of study. The location of each trap was marked by tying a piece of coloured tag/cloth on the nearest tall vegetation/plant. The trapped rats were identified and target rat species (gerbil) were tagged. The tag carried the specimen number along with other data such as location, capturing date and sex of the rat. Before re-setting the same trap, it was cleaned up of blood, flesh or any other contamination.

Dissection and morphometry

The trapped specimens were brought to the laboratory for standard morphological measurements including body weight by using a digital weighing balance and head to body length, head to tail length, tail length, hind limb, fore limb and length of ear) by using Vernier calliper. The trapped specimens were also categorized into distinct age classes (adult or juvenile) based on their body weight following the criteria used by Panti-May *et al*. (2012). The stomachs were removed by cutting the oesophagus approximately one cm above the stomach and one cm below the duodenum and stored in individual containers with 70% alcohol until contents were examined.

For micro-histological analysis of stomach contents, epidermal cells, including occurrence and position of specialized epidermal cell types were used to identify plant fragments in microscope slides prepared from stomach contents (Holechek *et al*., 1982). Micro-histological techniques, for preparation of reference samples and stomach contents were used following Holechek *et al*. (1982) and Sparks and Malechek (1968).

Reference plant material

During the trapping session of specimens from the field, samples of natural wild vegetation present in the study area were also collected and identified for the purpose of reference plant materials to confirm and classify plant fragments recovered from the stomach contents of the rat species. Two specimens of each reference plant were collected at growing periods of crop plants. The wild vegetation (*viz*., grasses, herbs and shrubs) were also collected frequently in the non-crop season because they could be identified only at flowering stages. All the collected plant material was dried at 60° C for 48 h for preparation of micro-histological slides and also for identification and record.

Light microscopic slides preparation

For stomach content analysis, separate micro-histological slides were prepared from different parts of the reference plants for identification of distinguishable cellular characteristics of plant materials found in the stomach. The segregated materials were dried at 60–65°C and weighed up to 0.1 mg accuracy. Some plant materials were not identified at macroscopic level were processed for micro-histological analysis following the modified methods described by Baumgarther and Martin (1939) and Sparks and Malechek (1968). The stomach contents were rinsed and a standardized amount was placed on a slide using a metal template. Dibutylphthalate polystyrene xylene (DPX) mountant was placed on the slide and mixed, a cover slip was added and observed under compound microscope (IM-900 IRMECO GmbH). The reference plant material was prepared likewise, but dried plant material was mixed with 10% NaOH solution for 20-30 s to clear tissues before rinsing. The plant materials on the slides were identified by comparing the characteristics of known cells (reference slides) with unknown cells (micro-histological slides of stomach contents). Four slides from each stomach sample were prepared for identification. All slides were labelled using animal number, date and area of the specimen.

RESULTS

Analysis of 30 stomach samples of Indian gerbil revealed a total 18 food items including crops, wild vegetation, mammalian hairs and insects (Table I, Fig. 2). The results showed that Indian gerbil was omnivorous and the relative proportions of its diets differed significantly among seasons. The most frequently consumed food items by this particular rodent species was mallah *Ziziphus nummularia* (19.89%), followed by khabbal grass *Cynodon dactylon* (16.02%), wheat *Triticum aestivum* (15.86%), *Sorghum bicolor* (14.89%), *Zea mays* (13.57%), sarson *Brassica campestris* (12.23%), millet *Pennisetum glaucum* (10.56%), ground nut *Arachis hypogaea* (10.03%), barley *Hordeum vulgare* (8.54%), mako *Solanum nigrum* (8.67%), prickly chaff flower *Achyranthes aspera* (6.01%), taramirs *Eruca sativa* (5.78%), clover *Medicago* spp. (5.67%), dab grass *Desmostachya bipinnate* (2.02%) and sagebrush *Artemisia dubia* (0.89%). As regards percentage (%) frequency of food item as animal matter i.e., insects (2.87%) were consumed slightly more frequently than mammalian hairs (1.06%).

Table I. Seasonal variation in consumption of different food items of percentage (%) frequency (Mean ± S.E) of the Indian gerbil (*Tatera indica*), recovered from the stomach, inhabiting agro-ecosystem of Pothwar Plateau.

Food items	Autumn 2018 (n=6)	Winter 2019 (n=9)	Spring 2019 (n=7)	Summer 2019 (n=8)
Crops				
Triticum aestivum	-	34.25 ± 5.75	24.25 ± 0.89	2.75 ± 0.89
Brassica campestris	-	26.50 ± 0.67	8.75 ± 0.57	1.00 ± 1.00
Arachis hypogaea	5.06 ± 0.59	-	-	15.50 ± 1.76
Sorghum bicolor	13.25 ± 1.65	11.50 ± 1.25	5.75 ± 2.25	13.00 ± 0.79
Pennisetum glaucum	12.25 ± 1.00	8.50 ± 0.89	6.50 ± 2.18	12.00 ± 1.03
Zea mays	3.00 ± 2.00	9.75 ± 0.50	3.50 ± 1.26	8.75 ± 0.84
Hordeum vulgare	-	17.75 ± 0.75	18.50 ± 1.45	0.75 ± 0.73
Eruca sativa	1.00 ± 1.00	15.00 ± 1.24	14.75 ± 0.78	1.00 ± 0.58
Wild vegetation				
Ziziphus nummularia	8.75 ± 1.50	23.00 ± 1.25	28.75 ± 1.25	3.00 ± 0.67
Cynodon dactylon	11.25 ± 0.56	13.25 ± 2.00	9.25 ± 1.67	3.75 ± 1.65
Solanum nigrum	17.25 ± 0.65	4.25 ± 0.25	6.75 ± 0.67	4.25 ± 1.84
Medicago spp	14.25 ± 1.25	9.50 ± 1.03	4.00 ± 1.35	2.75 ± 1.11
Achyranthes aspera	11.25 ± 0.50	10.00 ± 1.50	5.75 ± 2.02	0.75 ± 0.75
Artemisia dubia	0.75 ± 0.73	6.00 ± 1.06	4.75 ± 2.14	1.75 ± 1.18
Desmostachya bipinnata	3.50 ± 0.89	4.50 ± 0.98	1.50 ± 0.96	1.75 ± 1.56
Chenopodium album	2.25 ± 1.01	9.25 ± 1.50	16.00 ± 2.38	3.25 ± 1.97
Hairs	28.00 ± 1.41	-	-	-
Insects	-	-	-	27.25 ± 1.43
Unidentified items	4.00 ± 1.30	2.50 ± 1.50	4.37 ± 2.96	1.50 ± 1.26

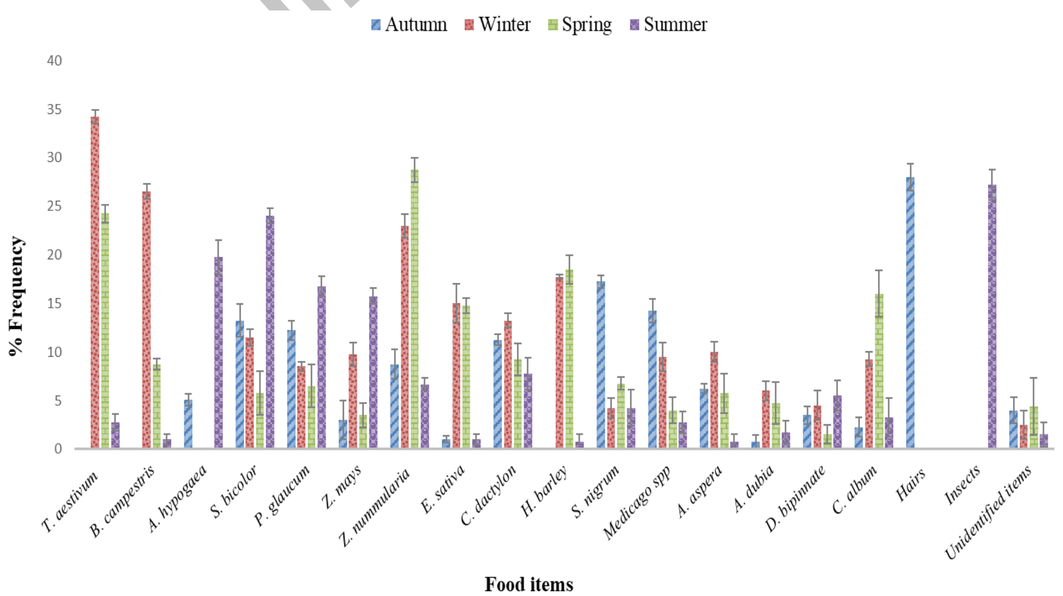

Fig. 2. Percentage frequency of different food items consumed by Indian gerbil during different seasons in the study area.

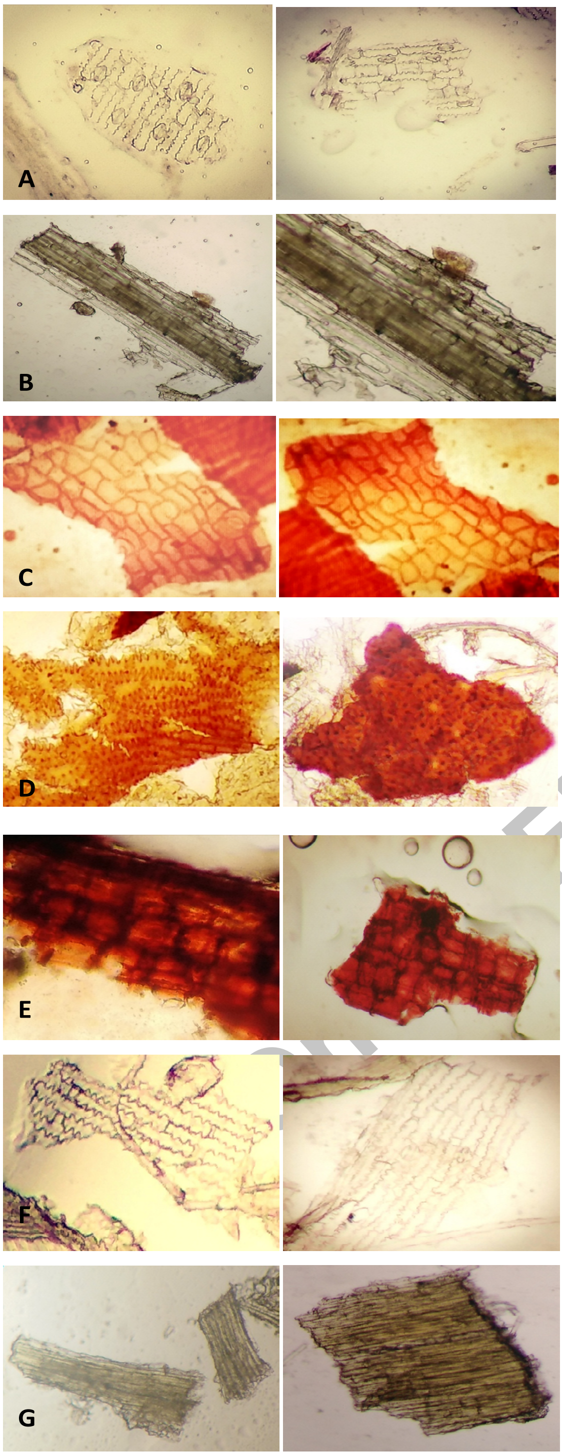

Fig. 3. (A-G) Micro-photographs of different food items recovered from the stomach of Indian gerbil (*Tatera indica*) compared with reference slides.
A, *Sorghum bicolor*; B, *Triticum aestivum*; C, *Arachis hypogaea*; D, *Ziziphus nummularia;* E, *Cynodon dactylon;* F, *Hordeum vulgare;* G, *Desmostachya bipinnate.*

During autumn season six stomach samples of Indian gerbil were collected and 14 food items were observed during this season. Maximum contribution of percentage frequency was the mammalian hairs (28%) (Table I, Figs. 3, 4B), along with the consumption of various natural vegetation including mako (17.25%), clover (14.25%), khabbal grass *Cynodon dactylon* (11.25%), malla *Ziziphus nummularia* (8.75%), prickly chaff flower *Achyranthes aspera* (6.25%), dab grass *Desmostachya bipinnate* (3.50%), bathu *Chenopodium album* (2.25%) and sagebrush *Artemisia dubia* (0.75%). Among the cereal crops, maximum utilization of sorghum (13.25%) was observed followed by millet (12.25%) and less frequently consumed crops were groundnut (5.06%), and maize (3%).

Nine stomach samples of Indian gerbil were collected during winter season (Nov 2018 - Feb 2019) from the study area. Their analysis showed that 16 food items were consumed by the gerbil including crops and wild vegetation. Among the crops groundnut (34.25%) dominated over the other seasonal cereal crops followed by mustard (26.50%), barley (17.75%), *Eruca sativa* taramira (15%) and sorghum (11.50%). Among the wild vegetation, maximum consumption of *Ziziphus nummularia* (23.00%) was observed while the minor preferred food item was *Chenopodium album* (9.25%) (Table I, Fig. 3).

The analysis of 16 identified food items recovered from seven stomach samples of Indian gerbil revealed the consumption of wheat at maturity stage during spring season being frequently higher and decreased utilization of herbs, grasses and shrubs in wheat growing season. During summer season, eight stomach samples were collected and their analysis revealed 17 food components during this season. Maximum contribution of percentage frequency was by the insects (27.25%) along with the consumption of summer crops including millet and maize (Table I, Figs. 3, 4A). However, utilization of wild vegetation during this season was wheat, sarson, barley, mako *Solanum nigrum*, khabbal grass, mallah, bathu, clover (Table I, Fig. 3). Two-way analysis of variance was used to determine the variation in the occurrence of major food items in the diet, across different seasons. Analysis of variance (ANOVA) later followed by least significance difference (LSD) revealed significant differences during cropping season winter (wheat) and non-cropping season autumn ($F = 1.88$, $df = 18$, $P < 0.05$). The frequency of different food items of cropping and non-cropping season (summer and monsoon) showed the significant difference ($F = 1.15$, $df = 18$, $P < 0.05$) and the remaining unidentified food items were non-significant to each other ($F = 1.10$, $df = 18$, $P > 0.05$). The analyses were performed using Statistical Package for Social Sciences (SPSS) software (Version 16.0).

Fig. 4. (A) Micro-photographs of Insects (B) Light microscopic photographs of hairs of Indian gerbil (*Tatera indica*) inhabiting agro-ecosystem of Pothwar Plateau.

DISCUSSION

Our results showed evidently that the Indian gerbil is omnivore and opportunist consumer. The difference in the utilization of cereal crops and specific plant species consumed corresponded with the crop stages, seasonal variation, favourable weather conditions, moderate temperature and photoperiod. Eighteen food items were recorded from the stomach of Indian gerbil including crops, wild vegetation, mammalian hairs and insects which showed that the relative proportions of its diet differed significantly among seasons. As in present study, Indian gerbil mainly consumed increasingly on the grains of the wheat at maturity during the spring season when the formation of nut started and crop plants became "milky" which was supported by a previous study conducted by Munawar *et al*. (2018) who reported that at the field boundaries under the wild vegetation, gerbil population was more or less stable and it consumed most of the wild habitat resources at field boundaries during non-crop season throughout the year to sustain its population. This rat is supposed to spend most of its time at surface feeding during the spring, when the climatic condition is favourable and has the security under crop shelter at the time of maturity stage of wheat crop. During this study, it has been observed that this species is known to leave the wheat fields well before the crop is harvested and breeding activity reaches its peak. Hussain (1989) revealed the similar pattern in wheat agriculture area of Islamabad. There was an inverse proportion in utilization of wheat plants and seeds and the consumption of rhizomes of different grass species. Lathiya (1990) also found this pattern in bandicoot rat *Bandicota indica* existing in the rice field in lower Sindh. Food is essential for the maintenance of body functions and reproduction. The availability of food influences individual growth rates, reproductive success, population density and recruitment (Desy and Batzli, 1989)

In autumn (non-cropping season), consumption of wheat was not noticed in the stomach samples of gerbil. The mammalian hairs were observed from the diet of autumn season only which confirmed that gerbil is a cannibalistic species that had consumed its conspecific. This fact had earlier been reported by Prater (1980) that cannibalism on young ones is a normal phenomenon in gerbil rat in captivity as well as in the wild. The consumption of groundnut showed the highest frequency during winter, groundnut consumption was not reported in stomach samples in any other season. At peg formation stage and with the development of nuts/grains, the gerbil rats started feeding on them. It is supposed to be the most preferred food and as maturity stage approaches, the crop fields had moist soil with good stand of groundnut plants providing protection to the burrows (Munawar *et al*., 2018)

In the absence of cereal crop during non-crop period, they shifted towards the wild flora at field borders, the maximum consumption was observed in the summer season due to rainfall, which accelerated the growth of weeds and grasses, consequently the utilization of wild vegetation were significantly higher than the rest of the seasons. The summer diet has also shown higher consumption of insects and it gets support from the study of Prater (1980), who reports that insect availability increases during the summer season and therefore the proportion of insects and other arthropods rises to as high as 40% in their preferred diet. The results of present study also confirm the fact that Indian gerbil heavily consumes insects during summer. Lathiya *et al*. (2010) stated that insect and grass roots played an essential part in the food of rat species short-tailed bandicoot rat *Nesokia indica* in date palm orchards of district Chaghai Balochistan. In the month of August 19.5% of the diet were insects whereas in other months of the year the insects were reported as minimum food item (3.7 to 11.83% of the diet). Lowest utilization of cereal crop plants in summer was due to the lower cover and species diversity of plants seen in crop fields during this time, non-availability of crop seeds and grains and increased availability of grass seed in border habitats (Ellis *et al*., 1998).

Our results indicated that during the lack of crop food, roots of grasses/shrubs such as mullah, khabbal grass, bathu, ground nut, dabb grass and sagebrush play an actual leading role in the diet of gerbil. These wild grasses provide shelter and alternate food when there is no cultivation and at an early stage of crop growth. The summer flora recorded was relatively more diversified than those of other seasons. Observed variation in dietary choice of food and specific plant species with season and rodent species underscores the importance of scale at the level of food item identification and appropriate time intervals for assessment when designing studies of small mammals.

CONCLUSION

The effects of stochastic events such as aberrant climatic patterns, or deterministic events such as crop phenology and land use management techniques, affect population dynamics of the small mammal (rodents) assemblage in Pothwar region. These different patterns in biotic and abiotic environmental conditions may explain into different dietary patterns. Our study concludes that the Indian gerbil is a generalist consumer and it can change its feeding habits, depending upon the availability of food materials and suitable season. The increased utilization of crops as the growth stages approach maturity can cause damage and heavy losses. Therefore, the mixed type of wild natural flora provides balance alternate food to gerbil round the year for their survival that discourages serious damage to cereal crops and also inappropriate use of rodenticides that could cause decline of Indian gerbil populations from threshold level which consumes large quantities of insects and may destroy substantial quantities of insect pests of crops.

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Statement of conflicts of interest

The authors have declared no conflict of interest.

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