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Review Article

Feeding and Reproductive Ecology of Rodents: A Review

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Abstract

Rodents are the most populous and widespread vertebrate pest of agriculture. It is a major cause of crop losses in fields and storage grains resulting in huge economic losses annually. Despite its huge economic importance, little is known about the pest in terms of its habitat, feeding habits, reproduction patterns and population dynamics. Due to the lack of proper knowledge, rodents are one of the most difficult pests to control in the agro-ecosystems. The management practices that exist are mostly chemo-centric and are often unreliable in controlling the populations. Hence, to develop efficient management strategies, it is important to gain a better insight into the ecology of rodents, both feeding and reproductive. This paper attempts to discuss the feeding and reproductive ecology of rodents, specifically but not limited to the agro-ecosystem.

Keywords: Feeding ecology, Pest management, Reproductive ecology, Rodents, Vertebrate pest

Introduction

Vertebrates have found a rich source of food and shelter in agro-ecosystem. Out of all the vertebrate pests, historically rodents have been an ever-present pest of field and storage products. Hence, there have been major efforts to reduce and maintain the vertebrate pest population and the widespread damage caused by them (Witmer *et al.*, 1995). Rodents are almost found everywhere and are difficult to manage due to their enormous size. Rodents constitute the biggest group of mammals with around 2500 species having been reported from all around the world (Burgin *et al.*, 2018). Of the total rodent population, about 10% are considered as pests of agriculture, *i.e.*, about 200 species (Labuschagne *et al.*, 2016). Quick to adapt to any adverse environmental condition, they are polyphagous pests of crops like cereals, potato, sugarcane, vegetables and fruit crops (Witmer and Singleton, 2012). Rodent species like *Rattus* sp. and *Musa* sp. can cause damage amounting to 1-15% and even higher in some cases (Lund, 2015). Rodents are important pests of agriculture because they cause substantial damage to the crops in fields and also destroy the crops post harvest by feeding on the storage grain and vegetables (Elango *et al.*, 2022). The rodents feed on the germ which results in failure of germination in the grains and also are responsible for a reduction in the market value due to contaminate of grains with their urine, feces and hair (Ognakossan, 2017). Additionally, rodents also act as vectors of more than 60 zoonotic diseases like typhus, plague, trichinosis, etc. which have serious implications on health of humans (Meerburg *et al.*, 2009). World Health Organization estimates that approximately 400 million cases of rodent-related zoonoses are reported in humans annually (Colombe *et al.*, 2019). According to Cao *et al.* (2002) rodents were responsible for approximate losses of 25% and 25-30% in grains, in pre-harvest and post-harvest situations respectively, resulting in a loss of US$ 5 billion annually. Some common species of rodents found in India are: Indian field mouse, (*Mus booduga*), lesser bandicoot rat (*Bandicota bengalensis*), soft-furred rat (*Millardia meltada*), gerbil rat (*Tatera cuvieri*, *T. indica*), rat (*Rattus rattus*, *R. meltada*), short-tailed bandicoot rat (*Nesokia indica*) and five striped palm squirrel (*Funambulus pennanti*).

Vertebrate pest management still remains largely unexplored as compared to insect and disease management. Rodents make up the majority of the vertebrate pest population and are difficult to manage due to their peculiar behavioral characteristics. In developing countries like India, rodent population outbreaks have serious implications for food

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security as well as economic loss at all scales (Singleton *et al.*, 2010). Pest management techniques for rodents are heavily dependent on chemical controls like acute rodenticides (such as zinc phosphide), but the growing awareness with regards to harmful effects of chemicals has forced the scientific community to look for other eco-friendly options. Additionally, rodents are neophobic in nature and display bait shyness, hence, even rodenticides suffer from a drop in efficacy (Horak *et al.*, 2018). Due to the growing environmental concerns regarding the use of hazardous chemicals, scientists now prefer pest management measures that are sustainable and environment-friendly (Saw and Chowdhury, 2023). Ecologically based rodent management (EBRM), which has gained much popularity, has been successfully utilized for the management of rodent populations in the agro-ecosystem (Htwe *et al.*, 2012). However, it requires proper identification and thorough knowledge of the behavioral traits, biology and ecology of rodents (Lawton *et al*., 2022). This paper attempts to compile the data and work carried out on the feeding and reproductive ecology of rodents, which are essential for their management.

Feeding Ecology of Rodents

As per recent reports, about 101 species of rodents can be found in India belonging to 7 families, 89 subspecies and 46 genera (Pradhan and Talmale, 2009; Sharma *et al.*, 2015). Rodents damage the field crops by gnawing, feeding, hoarding of grains and contamination of end product (Parshad, 1999). A characteristic feature of rodents is their hoarding behaviour. Under laboratory conditions, *T. indica* continued hoarding of wheat and cereals until recovery of weight lost on previous diet (Kumari and Khan, 1979). Under choice tests between various grains and pulses, *T. indica cuvieri* tend to favour larger grains for hoarding (Srihara and Srihari, 1980).

While *R. rattus* is the most populous species found in both residential areas and fields, *B. bengalensis* is found most commonly in fields and vegetable gardens (Ahsan, 2022). A study on the behaviour of *B. bengalensis* during 2009-10 and 2010-11 reported that *B. bengalensis* displayed hoarding behaviour and collected food for the off-season @ 170.78 g burrow^{-1}. *B. bengalensis* dug burrows mean density of 20.33 ha^{-1} and 27.40 ha^{-1} in boro and sali rice, respectively. The average number of brood chambers observed was 1.41 with 2.97 food chambers and 5.47 surface openings (Gogoi and Borah, 2012). Also, the highest numbers of burrows were observed in bunds during the harvesting season while the rodents migrated to crop fields during ripening stage. The highest rodent populations are often observed in paddy fields. In the rice ecosystems of Assam, the damage caused by *B. bengalensis* showed an increase with crop growth and maximum damage rates of 4.14% and 5.78% cut tiller were reported during the ripening stage (Gogoi and Borah, 2013). A similar observation was made by Borah (2016), where maximum live burrow counts (44.91), trapping index (8.11%) and rodent damage in the form of cut tillers (8.11%) were observed at the harvesting stage. Although, the field rodent infestations started from the tillering stage, the damage recorded showed a steady increase with advancement of crop growth, reaching its apex during the harvesting stage. This population trend is not limited to rice ecosystems. Pea crop grown after harvesting of paddy in the same field also recorded the highest incidence at harvesting stage with the maximum live burrow counts being 36.11 and the trapping index and damage being 4.81% and 4.44%, respectively (Borah, 2021).

Inspection of the stomach contents of *R. meltada*, also known as soft-furred field rat, revealed that wheat and grains constitute about 63.3% of the total food, with seeds of fodder grass occupying 27.54%. *R. meltada* also fed on insects like Coleoptera, Hymenoptera, Dermaptera and Hemiptera. The diet of the rodent was also heavily influenced by seasonal variations (Rana and Advani, 1981). Shiels *et al*. (2013) found that the dietary niche of co-existing rodent species differed greatly which may give an idea about the resource use and resource competition of these species. The rodents fed on an aggregate of arthropods and plant materials. The damage levels of rice and wheat crops due to *M. meltada* were 17.8% and 28.3%, respectively. The highest density of populations was recorded at the post-harvest stage (Lathiya *et al.*, 2003). Variation in field cropping influenced the population dynamics of field rat, *Rattus argentiventer*. The highest populations were observed in single cropping systems, at the early reproductive stage in comparison to multiple cropping systems (Brotodjojo *et al.*, 2023).

Reproductive Ecology of Rodents

Thousands of years of evolution have shaped the reproductive patterns of individuals in order to ensure survival of young ones for the continuation of one's species. The abundance of a species and its population density is highly influenced by its reproductive mechanisms. High reproductive potential of rodents is a fairly recognized fact. In case of *B. bengalensis* found in the rice ecosystems of Bangalore, Karnataka, the peak reproductive period was recorded between September-November, with a mean litter amounting to 7.1. In general, the reproductive activity started from August and lasted up to late April with an anoestrous period in March-July. Interestingly, the glands responsible for reproduction exhibited a change in weight which correlated with seasonal changes. Lower body weight recorded during summer coincided greatly with peak breeding season and crop maturation (Srihari and Raj, 1988). Population cycle studies of rodents indicate that there is a 2-3 order increase in population density from low phase with <1 ind. ha^{-1} (Andreassen *et al.*, 2021). Rodents display high plasticity and rapid response which enables them to utilize favorable conditions like an abundance of food to their own advantage (Singleton *et al*., 2010). When fed on rice and wheat, pregnancy prevalence in *M. meltada* was 50% with a mean litter size of 6.2 (Lathiya *et al.*, 2003). Under field conditions, the peak breeding season for *T. indica* was recorded from March-May (Singh, 1961). In one oestrous cycle, *T. indica* has average pro-estrous, estrous, met-estrous and di-estrous stages of 0.61, 0.38, 0.62 and 1.37 days, respectively. Under

laboratory conditions, the breeding had a success rate of 88% within gestation period of 21-24 days. The females attained sexual maturity at 3-4 months (Sandhu and Singla, 2020).

Historically, rodent population dynamics have been correlated to seed fall. The analysis of a global dataset comprising of the study of 156 rodent-seed pairs from 37 studies, taken from published material, the seed and rodent abundance positively correlated to each other. Additionally, the study found that the density dependence that influences the growth rates of rodent populations were higher than the relative importance of seed abundance (Liu *et al.*, 2023). Over the decades, different hypothesis has been suggested to gather a more well-rounded information about the population dynamics and reproductive cycles of rodents. The inherent plant cycles hypothesis by Kalela (1962), suggests that the population cycle of rodents is heavily influenced by the peaks in plant production, which may be linked to the accessibility to nutritious food during that period. Although originally the plant production was used to refer to the nutritious plant parts (like flowers and berries), it has now been extended to include other plant nutrient levels (Andersson and Jonasson, 1986). On the other hand, the interaction cycle hypothesis, which has three slightly different variants, suggests that the reproductive cycle of rodents is linked to a decrease in food quality (Lack, 1954). High density of rodent populations vigorously feed on readily available plant biomass in fields, which eventually results in the decrease in either the nutritional quality or availability of plant biomass. The high feeding pressure due to peak rodent population induces the nutritional depletion of plants and also induces plant defenses (Schultz, 1964; Massey *et al.*, 2008). Lack of theoretical and mathematical analyses has however restricted the full acceptance or rejection of the various suggested hypothesis.

Reproductive cycle and potential of rodents is highly dependent on availability of food but abiotic factors also have a significant impact. It has been established that the reproductive rate in rodents varies on the basis of different habitats and climatic conditions. Abiotic factor like rainfall had a significant effect on the gestation and maturity of females. Previous studies have established a relationship between rainfall and productivity in rodents (Sluydts *et al*., 2007; Previtali *et al*., 2009). A study in temperate regions of Madagascar found that the female reproductive rates of *R. rattus* coincided with the local agricultural calendar. During rainy season, the reproductivity of rodents outside the houses showed an increase while the dry seasons saw a decrease. Based on the results, it was concluded that high rainfall during the early stages of crop production provide ideal conditions for rodents in the rainy season (Scobie *et al.*, 2023). The spatio-temporal patterns in *R. rattus* breeding activity also established a decline in breeding rates with an increase in population density in crop fields (Scobie *et al.*, 2024).

Influence of Bamboo Flowering on Rodent Population in NE India

There are at least 137 species of bamboo in India where seeding and flowering occurs after long or supra-annual intervals. Some common bamboo species reported from India are: *Bambusa arundinacea*, *B. nutans*, *B. tulda*, *etc*. The bamboo species mainly occuring in North East India are: *Dendrocaamus longispathus*, *D. strictus*, *D. hamiltonii*, *B. tulda*, *B. polymorpha*, *Melaconna baccifera*, *B. bambusoides*, *Pseudostachyum polymorphum* and *Phyllostachys bambusoides* (Sridhara and Rajendran, 2009). Flowering of bamboo has often been associated with rodent outbreaks and as a harbinger of famines in religious and historical beliefs. In recent times, population outbreak of rodents has had devastating effects on human communities (Aplin and Lalsiamliana, 2010). The pattern of bamboo flowering in the last century in North East India has coincided with simultaneous rodent population outbreaks. The most common rodent species that were observed to experience population outbreaks were *R. niviventer*, *R. r. brunneusculus*, *R. rattus* and *R. bowersi*. The peculiar phenomenon of the correlation between flowering of bamboo and increase in rodent population is not limited to India or even Asian countries but has also been observed in other bamboo growing areas of the world. The Chittagong area of Bangladesh which borders the Northeastern state of Mizoram has a huge populace of *M. baccifera.* About 30% bamboo seeds in this area have been damaged by rodents. Also, preliminary studies have led to the conclusion that *R. rattus*, which is the dominant species, goes through a seasonal breeding due to the availability of bamboo seeds (Belmain *et al*., 2010). Previously, some researchers had been unable to prove the connection between the bamboo flowering and population outbreak of rodents. However, now we know that the prolific breeding observed in rats is due to the high abundance of nutritive bamboo seeds and reduction in usual cannibalism due to plenty food (Pathak and Kumar, 2000).

The incidence and availability of rodent species varies from area to area. In Nagaland and Manipur, the dominant species recorded was *R. nitidus* while *R. rattus* was the predominant species in Mizoram. *B. bengalensis* is a major pest of paddy in Mizoram but it did not see a significant increase in population during the flowering season or "Mautam", as it is referred to as in the local language. Large populations of *R. nitidus* and *R. r. brunneusculus* were reported from rice fields during the flowering of *Bambusa tulda* (Chauhan, 2003). The rodents are attracted to seed shedding and the abundance in food increases the rodent population (Jeeva *et al*., 2009). Feeding on the bamboo seeds escalates the sexual activity of the rodents which increases the fecundity of the female greatly. On an average, the female rodent is capable of giving birth to 800 offspring during the flowering season. In Arunachal Pradesh, higher trap index and percent damage in rice ranging from 12.9-15.4% were observed during bamboo flowering in 2009 while in 2010, in the absence of bamboo flowering, lesser incidences amounting to 5.3-5.8% were recorded (Kumawat *et al*., 2014). The periodic flowering of bamboo after every 48 years causes huge ecological imbalance in the seven sister states of India (Singh, 2019).

Conclusion

Rodents cause significant damage to agro-ecosystems and also have a deleterious impact on the socio-economic scenario of the community. The reproductive and feeding patterns of rodents constitute important aspects of their ecology. Study of the population outbreaks, feeding and breeding patterns will assist in the development of population models which would allow efficient forecasting of the rise in rodent population or its damage. Rodents and vertebrate pests cause a great deal of damage to agricultural goods but the strategies present for their management is still lacking on many fronts. Extensive research and studies are required to explore and gain more traction about the rodent population, especially in relation to agriculture to enable better management.

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