

ECOLOGY AND MANAGEMENT OF *Bandicota bengalensis* (Gray) IN FODDER FIELDS

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of**

**MASTER OF SCIENCE
in
ZOOLOGY
(Minor Subject : Botany)**

DUPLICATE

By

**Mandeep Kaur
(L-2000-BS-198-M)**

**Department of Zoology and Fisheries
College of Basic Sciences and Humanities
PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA - 141 004**

2003

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CERTIFICATE - I

This is to certify that the thesis entitled, "**Ecology and management of *Bandicota bengalensis* (Gray) in fodder fields**" submitted for the degree of Master of Science in the subject of **Zoology** (Minor subject : **Botany**) of Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Mandeep Kaur** (L-2000-BS-198-M) under my supervision and that no part of this thesis has been submitted for any other degree.

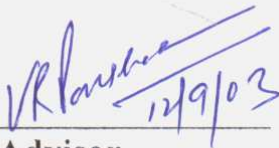
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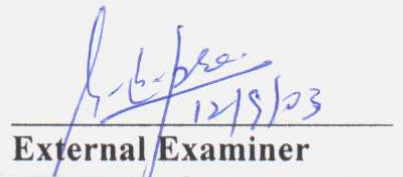
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CERTIFICATE - II

This is to certify that the thesis entitled, "**Ecology and management of *Bandicota bengalensis* (Gray) in fodder fields**" submitted by **Mandeep Kaur** (L-2000-BS-198-M) to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of Master of Science in the subject of **Zoology** (Minor subject : Botany) has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.


12/9/03

Major Advisor
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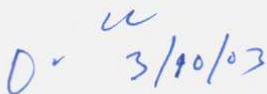

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ABSTRACT

Bandicota bengalensis and *Mus booduga* were the most common pests in fodder maize (*Zea mays*) and berseem (*Trifolium alexandrium*) fields located at village Dakha and at Punjab Agricultural University, Ludhiana. Few *Funambulus pennanti* and *Suncus murinus* were also trapped. Species-specific differences were observed in trapping success of two types of traps. *B. bengalensis* which weighed above 200g in body weight were trap killed more in snap traps and *M. booduga* (10-15g) were live trapped mainly in single rat traps. The sex ratio of trappability of female to male *B. bengalensis* was 1:1.6 in berseem and 1:2.75 in fodder maize fields. During the present studies, rodents began their activities at 25 DAS in berseem and 40 DAS in fodder maize fields. Agroecological conditions effect the colonisation and activities of rodents in fodder fields. *B. bengalensis* were trapped more from November to January and *M. booduga* in March in berseem crop. Unlike berseem fields, rodent activities regularly increased from 40 DAS upto maturity stages (70-95 DAS) in fodder maize fields. WSO (cracked wheat : groundnut oil : sugar, 96:2:2) was the preferred bait in comparison to other plant materials in both laboratory and field experiments. Stomach-content-analyses of *B. bengalensis* revealed that rats consumed *T. alexandrium*, *Brassica compestris* var. *sarson*, *Rumex maritimus* Linn. (janglipalak), *Cichorium intybus* Linn. (kashni) and *Medicago denticulata* Willd (maina) plant parts from berseem fields. Plant parts of *Z. mays*, *Physalis minima* Linn. (cherry) and *Pennisetum typhoides* (bajra) were identified in the stomach contents of rats trapped from fodder maize fields although in laboratory studies, inspite of these plants, consumption of *Euphorbia hirta* Linn. (dodhak), *Eleusine aegyptiacum* Desf (madhana) was also observed when offered in comparison to WSO bait. Rodent control with racumin (0.0375%) and bromadiolone (0.005%) resulted in 64.60 and 64.16% control success, respectively in berseem fields and 75.71 and 75.68%, respectively in fodder maize fields as determined by bait census with respect to reference field. Less per cent rodent control success in berseem and fodder maize may be due to rodent immigration from adjoining fields as a results of frequent disturbances in these due to ploughing, harvesting and flooding with irrigation and rainfall.

Keywords : Rodents, Berseem, Fodder Maize, Rodenticides, Stomach content analyses


Signature of the Major Advisor


Signature of the student

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Chapter - I

INTRODUCTION

Fodder maize (*Zea mays*) and berseem (*Trifolium alexandrium*) are highly nutritious and palatable foods for domestic animals. In Punjab, the area under fodder fields is approximately 0.78 million hectares and annual production of green fodder is 0.55 million tonnes (Anonymous 2002). The fodder maize is sown in the month of March onwards till the middle of September and is ready for harvesting within 50-80 days. Berseem is sown in October-November and is harvested in repeated cuttings from November to mid April.

Rodents are serious vertebrate pests of agriculture, horticulture and forestry. They inflict heavy losses to standing crops, stored food, house hold articles and pose severe threat to human and domestic animal health (Parshad and Ahmad 1996, Parshad 1999). By virtue of their extremely adaptable nature, highly intelligent patterns of behaviour and tremendous potential to multiply, they maintain their high populations which cause extensive damage to crop fields (Parshad 1999). Rodent damages ranging from 2% to 15% are common in agricultural crops and occasionally 25% to even 100% damage occur during conditions of rodent outbreak (Malhi and Parshad 1990, Sridhara 1992, Islam and Karim 1993, Jain *et al* 1993, Parshad 1999).

The fodder crop plays an important role in rodent ecology. Fodder fields face several waves of rodent immigration from adjoining fields as a result of

frequent disturbances in these due to ploughing, harvesting and flooding during irrigation and rainfall.

Bandicota bengalensis is a widespread pest of agriculture in wet and irrigated soils including fodder fields (Parshad 1999). During last decade in Punjab its population has increased with the increase of irrigation facilities, use of heavy machines and changes in the cropping patterns. This increase is mainly attributed to increased rice cultivation in Punjab and *B. bengalensis* is now most predominant in wheat-paddy-sugarcane growing region of the state (Parshad and Ahmad 1996).

In order to protect the crop fields from damages by rodents, there is a great need to improve the existing and develop new strategies for their management. The present strategies which are widely applied, involve the use of rodenticides, which generally provide the immediate solution to the rodent problems. Poison baiting of rodents with zinc phosphide is common in agricultural fields and recently coumatetralyl (racumin) and bromadiolone have been introduced for the control of both agricultural and commensal rodents (Parshad 1999).

According to Gosling (1980), wild plants (weeds) in crop ecosystem play important role in the establishment of mammalian pests. Because of different growth cycles, different species of weeds play important role in establishing the rodent populations in agricultural crops as these provide shelter to them and the food becomes available from weed plants earlier than from the crop plants.

Availability of food and shelter from weeds and crop plants within the crop fields and shelter facilitate the establishment of rodent population which may inflict severe damage to the crop subsequently. Moreover, availability and quality of food from weeds and crop plants affect the responses of rodent pests to rodenticide baits which due to unpalatability reasons are often avoided in the presence of abundant alternative food from sources within the crop field. However, except for some information of feeding ecology of rodents in paddy fields (Sridhara 1976, Nijjar 1991) no information is yet available about other crops.

In Punjab, rodents are serious pests of wheat and rice which are major crops of winter (*Rabi*) and summer (*Kharif*) season respectively (Prashad 1999). Following their harvesting during April and September-October respectively, fields are often found vacant and these inter-crop periods are generally referred to as lean periods, during which fields of vegetable, fodder, sugarcane, grasslands and forestry provide shelter to rodents. Therefore, such fields play an important role in sustaining rodent populations in agro-ecosystem of Punjab and other northern states (Parshad *et al* 1986, Malhi and Parshad 1993). Fodder, which is cultivated on a large area (0.78 ha) may play an important role in sustaining rodent populations. However, no information about the population dynamics, feeding ecology and responses of rodents to different methods of their control like trapping or rodenticide baiting is available. Therefore, the present studies were carried out on the following aspects of ecology and management of *B. bengalensis* in fodder fields;

- a) Population dynamics and activities of *B bengalensis* would be studied in relation to the different stages of fodder and the stages of crop in the adjoining fields.
- b) Gut contents of rats would be analysed to find out their feeding habits in the fodder fields.
- c) Responses of rats towards fodder plants in comparison to the preferred food will be studied to find out a suitable bait for them.
- d) Responses of rats towards baits in different seasons.
- e) Rodent control in the fodder maize and berseem fields.

Chapter - II

REVIEW OF LITERATURE

The rodents represent about 40% of mammalian species comprising some 1700 species belonging to 35 families (MacDonald and Fenn 1994). The rodent fauna of the Indian subcontinent is represented by 46 genera and 128 species (Roonwal 1987). Of these, 18 species are commensal and agricultural pests in India (Parshad 1999). In Punjab, eight species of rats and mice viz. *Bandicota bengalensis*, *Millardian (Rattus) meltada*, *Tatera indica*, *Golunda ellioti*, *Nesokia indica*, *Mus platythrix* have been recognised as pests of crop fields and two namely *Rattus rattus* and *Mus musculus* are pests in premises (Parshad and Ahmad 1996). Their populations have changed with changes in agroclimatic conditions and cropping patterns in Punjab (Parshad and Ahmad 1996).

Among the field species, *B. bengalensis* is most predominant in rice-wheat cropping system in Punjab (Parshad 1999). Both these crops are generally sown after deep tillage of fields. Deep tillage compel rodents to migrate to the adjoining bunds, sugarcane fields, fodder crops and waste lands (Ahmad *et al* 1990). Knowledge of various aspects of rodent biology and management has been the subject of various reviews and books (Prakash and Mathur 1987, Buckle and Smith 1994, Prakash and Ghosh 1992, Parshad 1999) and the available information relevant to the present studies has been reviewed in this section, though no specific information on rodents in fodder crops is available.

BURROW PATTERN AND DISTRIBUTION

Recent studies by Bationo *et al* (2002) showed that the burrowing rodents play an important role in regeneration of plant species and in dissemination of seeds in forest ecosystem. However, no such information is available about agricultural crops including fodder. *B. bengalensis* is a good digger and lives in self constructed elaborate burrow system, which often has large heaps of loose soil at openings (Chakraborty 1992). Both male and female occupy separate burrows. The burrows often had brood chamber at the maximum depth (Karim 1990). Rajak *et al* (2000) recorded 13.72 m² area covered by burrow system of *B. bengalensis* in pea fields and in sugarcane fields burrows were less extensive. Average depth of the burrow was 18.36 cm in sugarcane fields and 15.36 cm in the wheat fields. The total number of surface openings of the burrows were 13.4 in wheat and rice fields and 6.0 in sugarcane fields. The maximum number of food chambers (2.4) were recorded in wheat fields and minimum in pea fields. The amount of hoarded material in food chamber was maximum in wheat (average 1.27 kg/burrow system) and minimum (0.11 kg/burrow system) in sugarcane fields. .

FOOD PREFERENCES OF RODENTS

Rodents are versatile in feeding behaviour and choice of their food depends on their immediate environments and seasonal changes in food source (Gosling 1974). Food selection in rodents is determined by the factors such as taste, odour and texture (Bullard and Shumake 1977; Parshad and Jindal 1991).

According to Rana *et al* (1992) selection of food/bait by rodents depends more on taste rather than on its texture and nutritive values, while Vickery *et al* (1994) observed that *Peromyscus maniculatus* preferred the energy rich protein food in laboratory feeding trials.

Innate and learned behaviours influence the food preferences of rodents (Marsh 1991, Perez *et al* 1998). According to Naganuma *et al* (1973) the preferences for a particular diet in Norway rats depend more upon its flavour. The post-ingestive actions of glucose can condition substantial increase in its flavour acceptance as well as flavour preference by rats (Perez *et al* 1998). Role of olfaction in food preferences of mice studied by olfactory bulbectomy showed that olfaction is not essential for the formation of food preference behaviour (Lien *et al* 1999). Feeding experiments with bulbectomized mice showed that the preference for preferred food is abrogated by surgery implying the involvement of olfaction based memory on food preference behaviour.

Texture preferences are purely due to palatability reasons. Murids in general, prefer powdered, small sized and soft foods over large and hard grains (Pahwa and Srivastava 1983, Parshad and Jindal 1991).

Effects of several additives like sugar, salts, oils, and non-vegetarian food on food preference behaviour of various rodents have been studied by many workers (Prakash *et al* 1980, Khan and Khan 1980a, Suliman *et al* 1984, Ahmad and Parshad 1985, Amjad *et al* 1999, Kaur and Parshad 2001a, Kaur and Parshad 2001b, Kaur and Parshad 2002a, Kaur and Parshad 2002b). Semolina of wheat,

rice and millet grains was more preferred than their whole forms. Addition of cotton seed oil increased the bait acceptance by *B. bengalensis* (Ramana and Sood 1982) and arachis oil by *N. indica*, *R. meltada* and *Meriones hurrianae* (Chopra and Sood 1980, Chopra and Parshad 1983) and by Nile rat *Arvicanthis niloticus* (Suliman *et al* 1984). Addition of 5% groundnut oil increased the bait preference of *Funambulus pennanti* (Khan and Khan 1980b). The bait containing mustard oil is rejected by most of the rodent species (Chopra and Sood 1980). Addition of 7-10% groundnut oil enhanced bait intake significantly by *B. indica* while 2% salt and sugar had no effect (Sridhara and Srihari 1983). *B. bengalensis* showed more preferences for feeding rice bait with 2% groundnut oil and 5% sugar (Kaur and Parshad 2001b).

FEEDING ECOLOGY

Rodents generally prefer microhabitat with greater vegetation coverage, both along border and within fields (Alder *et al* 1991). Weeds form an important component of the diet of rodents (Fulk and Akhtar 1981, Drost and Moody 1982, Malhi and Parshad 1994) which selectively invade and cause more damage in weedy than in weeded crops (Parshad 1999).

Skorupska (1999) observed that the common vole (*Microtus arvalis*) ate most frequently cereals and grass seeds, vegetables stored in the field during winter as well as leaves of oil seeds. During snowy winter, when the voles can not find food, they destroy bark of young trees. In summer, favourite food of voles is legumes. Common voles also eat grasses which it draws into its holes. Wood rat

(*Neotoma megister*) has dietary differences within and between provinces. It eats green vegetation, hard mast, soft mast and fungi during all seasons (Castleberry *et al* 2002).

Ship rats (*Rattus rattus* L.) prefer small seed fruits over large seeded fruits (Delgado 2000). The nutrition value or presence of toxic compounds in fruits and seeds affect the dietary choices of pocket mice, *Liomys pictus* (Briones and Sanchez 1999) and squirrel, *Sciurus ingrami* (Bordignon and Monteiro 1999). During summer, the squirrels mainly feed on seeds of native trees of *Araucaria angustifolia* in autumn. When seeds of *A. angustifolia* were available, most of the forage was cached rather than consumed immediately for further use.

Kangaroo rat (*Dipodomys merriami*) also have scatter hoarding behaviour that may represent a compromise between rapid sequestering seeds, hence making them unavailable to non-digging competitors and spacing out caches, making them less vulnerable to pilferage by other rodents (Jenkins *et al* 1992).

The majority of rodents are seed eaters but some are insectivorous and some are versatile omnivores (MacDonald *et al* 1999). Bandicoot rats (*B. bengalensis*) are predators of *Laevicaulis alte* (slug) under natural conditions especially during night when slugs come out to feed and breed (Panigrahi 1999). They can also eat some edible molluscan species from water bodies. Shealer *et al* (1999) observed that gray squirrels (*Sciurus carolinensis*) feed on gall insects (*Solidago* spp.) regardless of size as they provide important dietary supplement for

squirrels during winter.

Chakraborty and Chakraborty (1984) observed that *R. rattus* preferred rice over other grains. Pearl-millet is preferred more than jawar, wheat, maize and paddy by *R. rattus* (Pahwa and Srivastava 1983) and *B. bengalensis* (Parshad and Jindal 1991).

Similarly, house mouse, *M. musculus bactrianus*, prefers pearl millet, rice and sorghum to other cereals and pulses (Mohana Rao and Prakash 1980). Preferences of rodents toward cereal baits in relation to availability of food from their natural habitat in crop fields of groundnut (*Arachis hypogaea*) and Lentil (*Lens culinaris*) were studied in the area infested by three different rodent species namely *B. bengalensis*, *T. indica* and *Mus* spp. (Ahmad and Parshad 1985). At the pod formation stage of groundnut crop the rat preferred to eat more of wheat meal containing groundnut oil than plain wheat grains. *B. bengalensis* has been found to prefer rice (Jalihal *et al* 1980) and millet to other cereals (Parshad and Jindal 1991).

B. indica showed clear preferences towards rice in its whole or divided form (Sridhara and Srihari 1983). *F. pennanti pennanti* preferred whole cereals and pulses to other foods (Khan and Khan 1980b).

STOMACH CONTENT ANALYSIS

Pelz (1987) by stomach content analysis observed that cereal grains and invertebrates make up the bulk of the diet of wood mice (*A. sylvaticus*) throughout the year. The presence of rice grains in stomach of *B. bengalensis* and

R. meltdada collected several months after the harvest indicated utilization of underground caches of rice (Fulk and Akhtar 1981).

Stomach content analysis of four common species of African rodents namely the giant rat (*Cricetomys gambianus*), the black rat (*R. rattus*), the multimammate rat (*mastomys natalensis*) and pygmy mouse (*Mus minutoides*) revealed vegetable items especially grass, grains and tubers in their diet (Iwuala *et al* 1980). The palmnut and kernals were present in the gut of *C. gambianus* and *M. natalensis*. Animal food components of the four rodent species comprised mainly of insects, vertebrate flesh and scales were also present in gut of *C. gambianus*. *R. rattus* gut content analysis revealed that fruits, leaves, stems, fungi, variety of invertebrates and also some vertebrates were present depending upon the habitat condition and availability (Clark 1982). Pieces of Arthropods and dicot leaves were detected in the stomach of *R. rattus* by Cole *et al* (2000). Analysis of stomach and caecum contents of *B. bengalensis* showed that in November and December , the primary food was the rhizomes of Johnson grass, *Sorghum halepense* (Valvano and Mitchell 1986).

RODENT DAMAGE AND MANAGEMENT IN CROP FIELDS

Rodents are serious pests of crops where conditions are conducive for their large populations and thus damages to the crops and stored food particularly in South Asia. Information about the crop losses and methods of management of rodents in different pest situations have extensively been reviewed and discussed (Prakash and Mathur 1987, Buckle and smith 1994, Prakash and

Ghosh 1992, Parshad and Ahmad 1996, Parshad 1999).

In India, rodent damage ranging from 2-15% is common in different agricultural crops and occasionally 25 to even to even 100% damage may occur during conditions of rodent outbreak. Mathur *et al* (1997) observed that crops vulnerable to rodent attack include rice, wheat other cereals, coconut and oil palm plantations.

Rodents are the serious pests of grasslands where *Microtus brandti* (Zhong *et al* 1999, Hou *et al* 1998), *Meriones unguiculatus* and *Cricetulus barbensis* (Hou *et al* 1998), *M. agretis* (Hansson 2002), mice, *Apodemus spp.*, (Jiang *et al* 1999), deer mouse, *P. maniculatus* (Pearson *et al* 2000), mouse (Petersen and Fischer 1999), pouched mouse, *Saccostomus mearnsi* (Metz and Keesing 2001) cause damage at all growth stages.

The main factors facilitating infestation by voles in grasslands are the cover and height of vegetation. The density of voles was low where the height of vegetation was > 190 mm but high where vegetation height was 30-130 mm (Zhong *et al* 1999). Both *M. brandti* and *M. unguiculatus* cause damage in natural and foraged grasslands (Hou *et al* 1998).

S. mearnsi prefers green vegetation to seed and has strong preference for forbs (Metz and Keesing 2001).

Rodent control is essential for reducing heavy damages to crops and other pest situations. An integrated management programme which included use of fencing (Zhong *et al* 1999) burrow baiting, control of weeds and control of

grazing intensity are suitable in grasslands (Fan *et al* 1999).

Use of rodenticides is the common approach to control rodents in agriculture (Buckle 1994). Zinc phosphide aluminium phosphide, warfarin, racumin and broamdiolone are recommended rodenticides in India (Parshad 1999). Among the acute rodenticides, zinc-phosphide is most commonly used and forms the basis of 80-90% of rodent control operations, particularly in agricultural situations (Parshad 1992, Parshad 1999).

Recently, 0.75% racumin has been commercialized in Indian to be used as 0.75% tracking powder or 0.0375% cereal bait. Racumin bait results in 50-70% control of *B. bengalensis* by placing the racumin baits in burrows (Malhi and Parshad 1995). Because of its low toxicity, chronic action, antidotability with vitamin K and high susceptibility of the most predominant pest species (*B. bengalensis*), racumin can be widely used in crop fields of India.

Bromadiolone is less toxic and effective to be used at 0.005% concentration in the bait. Bromadiolone baits are to be eaten for a longer period usually 24-48 h for complete mortality (Parshad 1986).

Chapter - III

MATERIAL AND METHODS

Present studies on the "Ecology and Management of *Bandicota bengalensis* (Gray) in Fodder Fields" were carried out in the field areas of Punjab Agricultural University (PAU), Ludhiana and farmers fields of village Dakha. Laboratory experiments were carried out in rodent research laboratory of the Department of Zoology and Fisheries.

3.1 POPULATION DYNAMICS OF RODENTS

Population dynamics of rodents in fields of fodder maize crop from May 2001 to September 2001 and in fields of berseem from October 2001 to June 2002 at farmers fields of village Dakha and at PAU Campus was studied from early growth stages till the harvesting.

Three fields each of one acre size were selected for both berseem and fodder maize crops. The experimental fields were located at more than 10 meters apart from each other. Population census of rodents were recorded at bi-weekly interval by three methods as described below :

3.1.1 Trapping

A field area of about 2 acre was selected at 15 days after sowing (DAS) of berseem and fodder maize each for trapping of rodents at different interval. The selected fields were not treated with rodenticides through out the crop seasons. Farmers frequently irrigated harvested part of the berseem field and thus the traps were placed in the remaining area of about 0.40 ha size. Three types

of traps viz. multi-catch wonder traps, single wooden rat traps and snap rat traps were used to trap the rodents (Fig. 1). Ten traps of each type in 2 lines of five each were placed in the fodder fields with trap to trap and line to line distance ranging from 8 to 12 meters depending upon the irrigation and harvesting operations. Metallic plates of snap and wonder traps were covered with pieces of paper to avoid rejection of traps by rats due to cooling/heating during winter and summer months, respectively. Out of these three types of traps, the multicatch traps did not trap any rodent. Therefore, the single rat and snap traps were used for trapping census.

Temperature data for winter months was taken from Agrometeorological Observatory, PAU, Ludhiana.

3.1.2 Track marker census of activity

Track marker census (TMC) was taken at 15 days interval in three replicated fields of 1 acre each of both berseem and fodder maize. Track markers (TM) were prepared using 18 x 18 cm white paper fixed with 6 x 6 cm polythene sheet coated with a mixture of xerographic ink and groundnut oil (1:1). These were placed at 10 m distance from each other in rows of 10, each in fodder maize and berseem fields. Because of irrigation in fodder fields, the dry areas of fields were selected for TM census. The following morning the TMs were examined and those showing foot and tail marks were considered positive for rodent activity.

3.1.3 Burrow census

The experimental fields had burrows of *B. bengalensis* and *M.*

Fig. 1 Three types of traps namely multi-catch wonder traps, single wooden rat traps and snaps rat traps used for trapping rodents from berseem (*Trifolium alexandrium*) and fodder maize (*Zea mays*) fields.



Fig. 1

booduga only as identified by their specific characteristics described by (Prakash and Ghosh 1992). Their live burrows were counted at 15 days interval in three replicated fields of one acre each of both the crops. To record the live burrows, the burrows were closed one day prior to the burrow census. On the following morning freshly opened burrows were counted as live burrows.

3.2 FOOD AND FEEDING ECOLOGY

3.2.1 Stomach contents

The lesser bandicoot rats (Fig. 2) which were killed with snap traps, were dissected to take out the stomachs out in the following morning and the rats which were trapped with single rat traps, were anaesthetized in the laboratory with chloroform and dissected to take out their stomachs. The stomachs were preserved in 10% formaldehyde solution. Before putting the stomach into formaldehyde solution, parts of oesophagus and small intestine which were cut along with it, were tied with a piece of thread in order to prevent the release of the stomach contents from either sides.

3.2.2 Collection and identification of reference plant materials from fodder maize and berseem fields

Weeds and crop plants (Table 1) were collected during month of March from berseem fields and during month of June from the fodder maize fields. These fields were the same from which the rats were trapped. Pre-dominant weeds from fodder maize fields were identified as *Physalis minima* L., *Euphorbia hirta* Linn., *Eleusine aegyptiacum* Desf. (Fig. 3) and less predominant as *Amaranthus viridis* Linn., *Digera arvensis* Forsk. Predominant weeds from

Fig. 2 The lesser bandicoot rat, *Bandicota bengalensis*



Fig. 2

Fig. 3 Fodder maize crop and other predominant weeds found within the field

A. Fodder maize (*Zea mays*)

B. Cherry (*Physalis minima*)



C. Dodhak (*Euphorbia hirta*)

D. Madhana (*Eleusine aegyptiacum*)



Fig. 3

Table 1 List of weeds in fodder maize/berseem

Name of weeds	Abundance
a) Berseem	
<i>Cichorium intybus</i> Linn (Kashni)	++++
<i>Medicago denticulata</i> Willd. (Maina)	++++
<i>Rumex maritimus</i> Linn. (Jangli palak)	++++
<i>Coronopus didymus</i> (Linn.) Sm. (Jangli halon)	+
<i>Polypogon monspeliensis</i> Desf. (Loomber ghas)	+
<i>Anagallis arvensis</i> Linn. (Billi buti)	+
<i>Brassica campestris</i> var. <i>sarsoan</i>	+
b) Fodder maize	
<i>Physalis minima</i> Linn.(Berry/ground cherry/berry)	++++
<i>Euphorbia hirta</i> Linn. (Dodhak)	++++
<i>Eleusine aegyptiacum</i> Desf. (Madhana)	++++
<i>Pennisetum typhoides</i> Linn.	+
<i>Amaranthus viridis</i> Linn. (Chaulai)	+
<i>Digera arvensis</i> Forsk. (Tandla)	+

+, less predominant; +++++, more predominant

berseem fields were identified as *Cichorium intypus* Linn., *Medicago denticulata* Willd., *Rumex maritimus* Linn. (Fig. 4), and less predominant weeds as *Coronopus didymus* (Linn) Sm, *Polypogon monspeliensis* Desf. and *Anagallis arvensis* Linn. The plants were identified as per the description given by Nandpuri *et al* (2000).

3.2.3 Preparation of reference slides of berseem, fodder maize and weed plants

Different parts (leaves, stems and roots) of plant were separated. They were grounded separately in pestle and mortar. The ground material was washed 2-3 times with water which was decanted off. The material was then tied in a muslin cloth.

Each material was stained with safranine (1% aqueous solution) for 1-2 minutes and dehydrated in alcohol series; 30%, 50%, 70%, 90%, 100% with 3-5 minutes in each grade. Before proceeding to 100% alcohol the material was stained in light green stain for 1-2 seconds.

For clearing, the material was passed through a mixture of absolute alcohol and xylene (25:75) and xylene (100%) by keeping it for 5-10 minutes in each solution. The plant material was released from the muslin cloth in pure xylene before mounting it on the slides with DPX mountant (Nijjar 1991).

3.2.4 Preparation of slides of stomach contents

After giving a slit into the wall of the stomach, its contents were released into water taken in a petridish. The stomach contents after separating the cereal bait were washed 2-3 times with water. Microscopic identification of stomach contents was carried out and different pieces were scored as plant and

Fig. 4 Berseem crop and other predominant weeds found within the field

A. Berseem (*Trifolium alexandrinum*)

B. Kashni (*Cichorium intybus*)



C. Maina (*Medicago denticulata*)

D. Jangli Palak (*Rumex maritimus*)



C



D

Fig. 4

animal material. The animal materials were preserved in 10% formalin solution. The plant materials of stomach contents were stained with safranin and light green stain as in the preparation of reference slides of fodder maize, berseem and weed plants.

3.2.5 Identification of stomach content

Five slides of the plant material from each stomach were used for the identification of the stomach contents. The identification of various parts of different plants eaten by rats collected from the fields was done by comparing with their reference slides. Epidermal pattern, stomata and trichomes were the main features which were taken into account for identification of the fragments of plant material from the stomachs of *B. bengalensis*. Plants fragments on the slides were identified and assigned to fodder maize, berseem, weeds and unidentified material. Animal matter was tentatively identified as insect and animal body part.

3.3 RESPONSES OF RATS TOWARD BAITS IN LABORATORY

3.3.1 Collection and maintenance of rats

For laboratory trials, both male and female rats of *B. bengalensis* were trapped from PAU, Ludhiana fields. They were acclimatized individually in cages for atleast 15 days before the commencement of the experiments. During this period they were fed upon broken wheat, containing 2% sugar powder and 2% groundnut oil (WSO mixture) and water was provided *ad libitum*. Metallic trays were kept under each cage for the collection of faeces and spilled food. Food and water were replenished daily. The metallic trays were cleaned daily in order to

maintain hygienic conditions in the laboratory.

3.3.2 Grouping of rats

Mature healthy rats (n = 6, 3 males and 3 females) after 15 days of acclimatization in the laboratory were weighed and caged individually on day one of five-day feeding experiment.

3.3.3 Bi-choice feeding test

Bi-choice test was performed to study the choice in feeding of WSO (Semolina of wheat, sugar and groundnut oil, 96:2:2) and plant materials (fodder maize/berseem/predominant weed plants) in different trials under laboratory conditions. For these trials, two laboratory cages were joined together through their opening with the help of wires as shown in Fig. 5.

Each bait preference test was conducted with six adult bandicoot rat (3 males and 3 females). After 15 days accilimatization, 20 grams each of two foods i.e. plant material and WSO mixture were offered to six rats individually for five days. Food and water were replenished daily. Food cups were rotated daily to avoid the effect of any site preferences of feeding. The records of daily food consumption from all food cups were maintained during the test period of five days by weighing the unconsumed and spilled food. Daily consumption of plant material eaten by each rat was calculated as below :

$$\text{Daily consumption of plant material} = W_1 - (W_2 + W_3)$$

W_1 , total amount offered

W_2 , left over plant material

Fig. 5 Double laboratory cage used for bi-choice feeding experiments



Fig. 5

W₃, lost of water by evaporation

Loss of moisture by plant material was noted by placing the same weight of plant material in a cage in the laboratory environment where experimental rats were kept. A time interval of two days was also given between feeding trials of two different plants and rats were accilimatized to feed on cracked wheat during these days.

3.3.4 Responses of rodents toward baits in fodder maize and berseem fields

Acceptance of bait materials was studied in the fodder maize from June 2001 to September 2001 in PAU fields and in berseem fields from November 2001 to April 2002 at farmers fields of village Dakha.

One field each of 1½ acre size of berseem and fodder maize was selected. Two types of baits were prepared to check their acceptance by rats. One bait was a WSO mixture and other was WMFSO (wheat flour 48 : maize flour 48 : powdered sugar 2 : groundnut oil 2) mixture. Both these baits were placed simultaneously on 20 places for 1 day. The following morning consumption by rodents was recorded by weighing the unconsumed baits.

3.4 CONTROL OF RODENTS IN FODDER FIELDS

Eight fields infested with rodents were selected at Dakha village to determine field efficiency of 0.0375% Racumin and 0.005% bromadiolone. Experiments of rodent control were carried out in berseem during early February and fodder maize during August - September.

3.4.1 Formulation of bait material

Bromadiolone (0.005%) bait was prepared by mixing its 20 g of 0.25% concentrate powder in 980 g of WSO mixture and racumin (0.0375%) bait was prepared by mixing 50 g of racumin powder (0.75%) in 950 g of WSO - mixture.

3.4.2 Control of rats in berseem fields

A group of three fields each of 1 acre size was used for baiting 0.005% bromadiolone and 0.0375% racumin separate by while a group of two fields was kept as reference in which no treatment was given. These three groups of fields were located more than 100 meters distance from each other.

Burrow baiting was done with rodenticide baits at bunds and peripheries of the experimental fields. Baits were not placed openly within the fields to avoid contamination with fodder and to avoid their spoilage by water during frequent irrigation of berseem fields by the farmers.

3.4.3 Control of rats in fodder maize

Control of rodents in fodder maize was carried out with bromadiolone and racumin baits in same way as in case of berseem by burrow baiting within and around (upto 1-2 meters) the experimental fields.

3.4.4 Efficacy of rodenticide application

Efficacy of rodenticide application in each field was determined by pre- and 15 days post-treatment live burrow count and census baiting. Live burrows were counted in the same manner as described in section 3.13 and for

census baiting, 20 g plain bait was placed at 20 points (dry locations) each, within the field in 2 rows with 10 metres distance among baiting points.

3.5 STATISTICAL ANALYSIS

Data of TMC, Burrow census and bait preferences of rodents in fodder fields was analysed by analysis of variance (Gupta 2001). Significance of the difference among mean daily intake (MDI) of 2 different foods at laboratory condition and differences between mean consumption of two foods at fodder fields was determined by student's t-test (Gupta 2001).

RESULTS AND DISCUSSION

4.1 POPULATION DYNAMICS OF RODENTS

Changes in population and relative abundance of different species of rodents during crop seasons of berseem (*Trifolium alexandrinum*) and fodder maize (*Zea mays*) were studied by monthly trapping, track marking activity and live burrow census in farmer's fields of village Dakha and in fields of PAU, Ludhiana.

4.1.1 Trapping in berseem fields

Results of live trapping of rodents with single rat traps (SRT) and kill trapping with snap traps (ST) by placing 10 traps in 2 rows of 5 each/0.40 hectare field area of berseem crop are shown in Table 2. No rat was trapped upto 30 DAS of the crop in October and first half of November. Trapping success was zero in month of April and May when there was a plenty of food in the adjoining wheat fields.

During the months from October 2001 to May 2002 a total of 25 specimens from 300 trap nights of SRT (8.3% trapping success) and 13 specimens from 300 trap nights of ST (4.3%) were trapped. Per cent trap success with SRT was maximum (12.5%) in the months of November and March and was relatively less in the cold months of December to February. However, with snap traps, more rats were kill-trapped near bunds and areas without irrigation during November to January than in February and March.

Table 2 Trapping of rodents from fields of berseem (*Trifolium alexandrium*)

Month	DAS	Trap type	Trap nights (nights of trapping x traps)	Total trapping (% success)	<i>Bandicota bengalensis</i>	<i>Mus booduga</i>	<i>Funambulus pennanti</i>
Date of sowing - 15 October 2001							
October 2001	15	SRT	1 x 10	0(0)	0	0	0
		ST	1 x 10	0(0)	0	0	0
November 2001	30	SRT	4 x 10	5(12.5)	1	4	0
		ST	4 x 10	3(7.5)	3	0	0
December 2001	48	SRT	4 x 10	4(10)	0	4	0
		ST	4 x 10	4(10)	4	0	0
January 2002	79	SRT	5 x 10	3(6)	1	1	1
		ST	5 x 10	4(8)	3	1	0
February 2002	120	SRT	4 x 10	3(7.5)	0	3	0
		ST	4 x 10	0(0)	0	0	0
March 2002	148	SRT	8 x 10	10(12.5)*	0	9	0
		ST	8 x 10	2(2.5)*	1	0	0
April 2002	183	SRT	2 x 10	0(0)	0	0	0
		ST	2 x 10	0(0)	0	0	0
May 2002	208	SRT	2 x 10	0(0)	0	0	0
		ST	2 x 10	0(0)	0	0	0
Harvested on 27 May 2002							
		SRT+	30 x 10	25(8.3)	-	-	-
		ST+	30 x 10	13(4.3)	-	-	-
		Total	30 x 20	38(6.3)	-	-	-

DAS = Days after sowing

SRT = Single rat trap

ST = Snap- trap

* Includes trapping of one schrew (*Suncus murinus*) each with SRT and ST

+ Mean % success in 300 trap nights each with SRT and ST

Table 3 Number of rodents captured with single rat and snap traps in berseem field

Trap type	<i>Bandicota bengalensis</i>	<i>Mus booduga</i>	<i>Suncus murinus</i>	<i>Funambulus pennanti</i>
Single rat trap	2	21	1	1
Snap trap	11	1	1	0
Total number (%)*	13(34.2)	22(57.9)	2(5.3)	1(2.7)

* Figures in parentheses are the percentage of the total number of rodents trapped.

Table 4 Body weights and sex ratio of *Bandicota bengalensis* trapped from berseem field

Sex	No. of rats	Mean body weight (g) (Mean±SD)	% trapping
Female	5	227.0±48.1	38.5
Male	8	202.5±9.7	61.5

Of the total 38 animals trapped from 0.40 ha area of berseem field, 34.2% were *Bandicota bengalensis*, 57.9% *Mus booduga* 2.7% *Funambulus pennanti* and 5.3% *Suncus murinus* (Table 3). Thus, *B. bengalensis* and *M. booduga* were the predominant rodent species in berseem crop. Per cent trapping of male *B. bengalensis* was 61.5 as compared to 38.5 of female rats (Table 4).

Highly significant differences due to trap type and rodent species trapped were evident during the present studies (Table 3). Excluding the incidental trapping of one *F. pennanti* and two *S. murinus* from the total trapping, it was evident that SRT live trapped 91.3% *M. booduga* compared to 8.7% *B. bengalensis*. Whereas, snap traps killed 91.7% *B. bengalensis* compared to only 8.3% *M. booduga*.

4.1.2 Trapping in fodder maize fields

Data of monthly trapping of rodents with 10 SRT and 10 ST each in two rows of five/0.40 ha of fodder maize is summarised in table 5. Per cent total trapping success in early sown fields was 7.9 compared to 9.0 in late sown fields with 280 and 100 trap nights, respectively. Except for two *M. booduga* trapped in late sown field in July, rodent activities were negligible till 30 DAS in both early and late sown fields of fodder maize. In early sown fields maximum trapping occurred in July whereas in late sown fields trapping performance remained almost same of July to September.

In fodder maize fields, five *S. murinus* and three *F. pennanti* were trapped, but the major rodent species comprised of *B. bengalensis* (54.6% in early

Table 5 Trapping of rodents from fields of fodder maize (*Zea mays*)

Month	DAS	Trap type	Trap nights (nights of trapping x traps)	Total trapping (% success)	<i>Bandicota bengalensis</i>	<i>Mus booduga</i>	<i>Funambulus pennanti</i>
Date of sowing - 7 June 2001 (Early sown crop)							
June	15	SRT	2 x 10	0(0)	0	0	0
2001		ST	2 x 10	0(0)	0	0	0
July	30	SRT	7 x 10	11(15.7)**	4	3	2
2001		ST	7 x 10	6(8.6)*	5	0	0
August	60	SRT	5 x 10	2(4)*	0	1	0
2001		ST	5 x 10	3(6.0)	3	0	0
Harvested on 21 August 2001							
		SRT+	14 x 10	13(9.3)	-	-	-
		ST+	14 x 10	9(6.4)	-	-	-
		Total	14 x 20	22(9.9)	-	-	-
Date of sowing - 5 July 2001 (late sown crop)							
July	15	SRT	1 x 10	2(20.0)	0	2	0
2001		ST	1 x 10	0(0.0)	0	0	0
August	30	SRT	2 x 10	2(10.0)*	0	0	1
2001		ST	2 x 10	2(10.0)	2	0	0
September	60	SRT	2 x 10	2(10.0)	0	2	0
2001		ST	2 x 10	1(5.0)	1	0	0
Harvested on 24 September 2001							
		SRT++	5 x 10	6(12.0)	-	-	-
		ST++	5 x 10	3(6.0)	-	-	-
		Total	5 x 20	9(9.0)	-	-	-

DAS = Days after sowing

SRT = Single rat trap

ST = Snap trap

* - Single shrew was trapped with ST in July (Early sown crop) and with SRT in August in both early and late sown crops.

** - Two shrews were trapped in July (Early sown crop) with SRT.

+ Mean % success in 140 trap nights each with SRT and ST

++ Mean % success in 50 trap nights each with SRT and ST

and 33.3% in late sown fields) and *M. booduga* (18.2 in early and 44.5% in late sown field) as given in table 6. In fodder maize, eleven *B. bengalensis* were trapped with ST and four with SRT.

These species specific differences in the trappability of SRT and ST relate to the size and response of rodents to the traps as *B. bengalensis* which are above 200 g body weight are killed by ST whereas, *M. booduga* which weighed about 10-15 gm were mainly trapped in SRT. SRT are wooden box type traps whereas, ST are metallic spring release traps. The differential response of *B. bengalensis* and *M. booduga* to both trap types may also relate to the night temperature affective to their activities and body weights. Due to its less body weight, *M. booduga* may escape from ST.

Sex ratio of trapped female to male *B. bengalensis* was 1:1.6 in berseem (Table 4) and 1 : 2.75 in fodder maize fields (Table 7). Trapping of more number of male than female specimens was also observed in *Mastomys natalensis* in which sex ratio of female to male was 1:1.35 (Yang 2001). More number of male rats are trapped due to their more nocturnal activity than females which may confine to burrows due to pregnancy and lactations (Chakraborty 1992).

4.1.3 Track marker activity (TMA) in berseem fields

Track markers (n=40 per 0.40 hectare) laid out in a 10 m² grid were marked positive generally by *B. bengalensis* with little or no response by *M. booduga* as identified by the size and appearance of foot and tail marks. The TMA of *B. bengalensis* was recorded at different stages of the crop and the results are

Table 6 Number of rodent captured with single rat and snap traps in fodder maize (*Zea mays*) fields

Trap type	<i>Bandicota bengalensis</i>	<i>Mus booduga</i>	<i>Suncus murinus</i>	<i>Funambulus pennanti</i>
Early sown field				
Live trap (SRT)	4	4	3	2
Kill trap (ST)	8	0	1	0
Total no. (%)*	12(54.5)	4(18.2)	4(18.2)	2(9.1)
Late sown field				
Live trap (SRT)	0	4	1	1
Kill trap (ST)	3	0	0	0
Total no. (%)*	3(33.3)	4(44.5)	1(11.1)	1(11.1)

* Figure in parenthesis are the percentage of the total number of rodent trapped

Table 7 Body weights and sex-ratio of *Bandicota bengalensis* trapped from fodder maize (*Zea mays*) fields

Sex	Number of rats	Mean body weight \pm SD	% trapping
Early sown field			
Female	3	196.7 \pm 4.7	25.0
Male	9	207.8 \pm 34.3	75.0
Late sown field			
Female	1	250.0 \pm 0.0	33.3
Male	2	205.0 \pm 5.0	66.7

summarized in table 8.

Significant variations ($P < 0.05$) in TMA occurred due to age (Days after sowing, DAS) of the crop with non-significant variations among the replicates (Table 9). TMA was almost negligible (5%) at 25 DAS, that increased to 40 and 48.33 on 40 and 55 DAS, respectively and showed subsequent decline at 70 DAS, thereafter. TMA again increased at 85 and 100 DAS which further declined and became zero at 145 DAS afterwards table 8. These variations in TMA appear to be related to the irrigation schedule adopted by farmers, harvesting of fodder, and availability of food in the adjoining fields of wheat crop.

4.1.4 Track marking activity (TMA) in fodder maize

Tracking papers (n=40 per 0.40 hectare) laid in a 10 m² grid in early and late fodder maize fields, were marked positive by *B. bengalensis* only and no sign of marking by *M. booduga* was evident as in case of berseem fields. Number of track markers marked by *B. bengalensis* and percent track marking activity at different stages of the crop are given in table 10.

Significant variations ($P < 0.05$) in TMA occurred due to age (DAS) of the crop in both early and late sown fodder maize fields with non-significant variations among the replicates in late sown and significant differences in early sown fields (Table 11). TMA was negligible at 40 DAS increased to 13.33 and 17.50 at 55 and 70 DAS, respectively in early sown crop. Unlike the early sown crop, in late fodder maize crop, TMA was recorded 9.18% at 40 days which increased to 38.33% and 43.33% at 55 and 70 DAS, respectively (Table 10). A

Table 8 Track marking activity of *Bandicota bengalensis* in berseem fields

Month	Days after sowing (DAS)	Positive track marks (Mean ± S.E.)	TMA (%) (n= 40)
Date of sowing - 21 October, 2001			
November (2001)	25	2.00±0.94	5.00
	40	16.00±2.16	40.00
December (2001)	55	19.33±0.98	48.33
	70	5.00±1.41	12.50
January (2002)	85	7.33±3.03	18.33
	100	11.33±0.54	28.33
February (2002)	105	4.67±1.19	11.68
March (2002)	130	0.67±0.54	1.68
	145	0.00±0.00	0.00
April (2002)	160	0.00±0.00	0.00
	175	0.00±0.00	0.00

Harvested on 10 May to 7 June 2002

TMA is percentage of the number of track marker showing tracks marks

Table 9 Analysis of variance of track marking activity of *Bandicota bengalensis* at different days after sowing (age) of berseem crop

Source	d.f.	M.S.	F-ratio	CD (5%)	G.M.	C.V.
Replicates	2	9.3964	1.38	NS		
Days after sowing (DAS)	10	149.690	22.13	4.429		
Error	20	6.764			6.182	42.07

d.f. = Degree of freedom
M.S. = Mean square
CD = Critical difference
G.M. = Geometric mean
C.V. = Coefficient of variations
NS = Non-significant

Table 10 Track marking activity of *Bandicota bengalensis* in fodder maize fields

Month	Days after sowing (DAS)	Positive track marks (Mean \pm S.E.)	Percent positive track marks (n = 40)
Date of sowing - 20 April, 2001			
Early sown field			
May (2001)	40	0.00 \pm 0.00	0
June (2001)	55	5.33 \pm 1.44	13.33
June (2001)	70	7.00 \pm 2.16	17.50
July (2001)	85	1.67 \pm 1.44	4.18
July (2001)	95	7.67 \pm 0.72	19.18
Harvested on 10 to 25 July, 2001			
Date of sowing - 14 June, 2001			
Late sown field			
July (2001)	40	3.67 \pm 1.90	9.18
August (2001)	55	15.33 \pm 4.06	38.33
August (2001)	70	17.33 \pm 1.19	43.33
September (2001)	85	17.00 \pm 2.05	42.50
Harvested on 18 to 25 September, 2001			

Table 11 Analysis of variance of track marking activity of *Bandicota bengalensis* at different days after sowing (age) of fodder maize crops

Source	d.f.	M.S.	F-ratio	CD (5%)	G.M.	C.V.
Early sown field						
Replicates	2	22.867	4.78	3.190		
Age (DAS)	4	53.833	11.25	4.119		
Error	8	4.783			6.33	34.53
Late sown field						
Replicates	2	60.083	3.22	NS		
Age (DAS)	3	126.888	6.81	8.627		
Error	6	18.638			13.33	32.78

- d.f. = Degree of freedom
M.S. = Mean square
CD = Critical difference
G.M. = Geometric mean
C.V. = Coefficient of variations
NS = Non significant
DAS = Days after sowing

subsequent decline in TMA was recorded at 85 DAS in early and late sown fields which again increased in early sown fields at 95 DAS.

4.1.5 Live burrow count of rodents at different days after sowing in berseem crop

Results of number of live burrows of rodents at different DAS in berseem fields are shown in Table 12. No live burrow of rodents was observed in berseem fields before 25 DAS and after 220 DAS.

Burrows of *B. bengalensis* were present only at peripheral bunds at 25 DAS and between 115 to 130 DAS. The maximum number (37.0 ± 3.39) of live burrows of *B. bengalensis* were present in December at 55 DAS. The lesser bandicoot rats started digging new burrows at several places but after initial digging upto 1 to 6" depth. They leave most of such new burrows and completely dig few burrows only. The number of marks partly due to new burrows were 0.70 at 25 DAS in November and 10 at 55 DAS in December. No new burrow digging activity was present from 145-235 DAS (Table 12). New burrow digging activity occurred only on peripheral bunds and not within the crop area because of frequent irrigation of the crop.

In case of *M. booduga* maximum number of burrows were present at peripheral bunds throughout the crop except at 190 DAS when burrows on peripheral bunds declined with corresponding increase within the field area. Significant differences occurred in the number of live burrows due to species and age (DAS) of the crop (Table 13).

Table 12 Live burrow counts of rodents in berseem (*Trifolium alexandrinum*) fields at different age of the crop

Month	Live burrow count/0.40 hectare (mean±S.E.) (n = 3)				New burrow digging activity sites/0.40 hectare (mean±SE)	
	Age (days after sowing)	<i>Bandicota bengalensis</i> Total live burrows	(Percent peripheral +with in fields)	<i>Mus booduga</i> Total live burrows	(Percent peripheral +with in fields)	<i>Bandicota bengalensis</i> Total live burrows/0.40 ha
Date of sowing -22 October, 2001						
November (2001)	25	3.33±0.98	(100.00+0.00)	0.00±0.00	(0.00+0.00)	0.66±0.54
December (2001)	40	27.00±5.66	(41.96+58.04)	0.00±0.00	(0.00+0.00)	8.33±3.31
	55	37.00±3.39	(27.92+72.08)	0.00±0.00	(0.00+0.00)	10.00±1.25
	70	7.33±1.19	(91.00+9.00)	0.00±0.00	(0.00+0.00)	4.00±3.27
January (2002)	85	8.00±1.69	(75.00+25.00)	0.00±0.00	(0.00+0.00)	7.67±2.42
	100	10.67±2.42	(65.60+34.40)	0.00±0.00	(0.00+0.00)	9.67±1.91
February (2002)	115	5.00±1.25	(100.00+0.00)	0.00±0.00	(0.00+0.00)	3.00±0.80
	130	2.00±1.25	(100.00+0.00)	5.66±2.84	(88.34+11.66)	1.00±0.47
March (2002)	145	0.00±0.00	(0.00+0.00)	8.67±1.52	(85.54+15.46)	0.00±0.00
	160	0.00±0.00	(0.00+0.00)	3.33±0.72	(100.00+0.00)	0.00±0.00
April (2002)	175	0.00±0.00	(0.00+0.00)	3.33±0.72	(100.0+0.00)	0.00±0.00
	190	0.00±0.00	(0.00+0.00)	1.67±1.36	(40.12+59.88)	0.00±0.00
May (2002)	205	0.00±0.00	(0.00+0.00)	0.67±0.54	(100.00+0.00)	0.00±0.00
	220	0.00±0.00	(0.00+0.00)	0.00±0.00	(0.00+0.00)	0.00±0.00
June (2002)	235	0.00±0.00	(0.00+0.00)	0.00±0.00	(0.00+0.00)	0.00±0.00
Harvested on 10 May to 7 June 2002						

Table 13 **Analysis of variance of life burrow-counts of rodents at different age of berseem crop**

Source	d.f.	M.S.	F-ratio	CD (5%)	C.V.
Replicates	2	18.956	1.78		
A	2	337.067	31.60	1.368	
B	14	188.746	17.69	3.060	
AB	28	117.527	11.02	5.300	
Error	88	10.668			89.08

- d.f. = Degree of freedom
M.S. = Mean square
CD = Critical difference
C.V. = Coefficient of variations
A = Factors (live burrow of *B. bangalensis*, *M. booduga* and new burrow digging activity)
B = Age (Days after sowing)

4.1.6 Live burrows of rodents at different days after sowing in fodder maize crop

The number of live burrows increased with age (DAS) of the crop in early and late sown fodder maize fields.

Maximum number of *B. bengalensis* live burrows i.e., 92.72 and 95.8 of the total live burrows at 40 DAS in early and late sown fields respectively were present on peripheral bunds, but at 70 DAS onwards more burrows were located within the fodder maize fields than on the peripheral bunds (Table 14).

New burrow digging activity marks were maximum (14.67%) with in fields in July at 95 DAS in early and at about 90 DAS (19.33%) at the harvesting stage in late sown fields. New burrow digging activity was only within the maize fields in contrast to that in berseem fields.

More number of live burrows of *M. booduga* occurred on peripheral bunds than within the crop fields of both early and late sown fodder maize (Table 14). The number of live burrows of *M. booduga* increased within fields in July (30.77%) at 95 DAS in early and in September (47.48%) at harvesting stage in late sown crop fields. Differences among number of live burrows at different DAS and also among the live burrows of *B. bengalensis*, *M. booduga* and new burrow diggings by *B. bengalensis* were statistically significant (Table 15). Variations in number of live burrows of rodents was due to excessive irrigation and availability of food in the adjoining areas.

The present studies clearly showed that *B. bengalensis* and *M. booduga* are the major rodent species in berseem and fodder maize crop fields.

Table 14 Live burrow count of rodents in fodder maize (*Zea mays*) at different age of crop

Month	Live burrow count/0.40 hectare (mean±S.E.) (n = 3)				New burrow digging activity site/0.40 hectare (mean±SE)
	Age (days after sowing)	<i>Bandicota bengalensis</i>	<i>Mus booduga</i>	<i>Bandicota bengalensis</i>	
		Total live burrows	Total live burrows	(Percent peripheral +with in fields)	Total live burrows
Date of sowing - 20 April, 2001					
Early sown crop					
May (2001)	40	4.67±1.22	7.67±1.70	(82.66+17.34)	1.67±1.40
June (2001)	55	6.00±0.94	10.33±0.98	(88.83+11.17)	1.67±0.98
	70	10.00±2.16	11.00±1.25	(46.70+53.30)	6.33±1.91
July (2001)	85	19.00±3.77	10.00±0.00	(35.11+64.89)	14.00±3.86
	95	27.00±2.94	13.00±0.47	(40.74+59.26)	14.67±2.13
	Harvested	32.33±2.37	18.00±2.94	(36.10+63.90)	5.00±2.36
Harvested on 10 to 25 July, 2001					
Date of sowing 14 June, 2001					
Late sown crop					
July (2001)	40	16.00±2.87	4.67±0.72	(95.8+4.19)	0.0±0.00
August (2001)	55	26.00±4.56	12.00±2.49	(69.2+30.77)	3.33±1.52
	70	38.67±9.02	16.00±2.36	(58.6+41.38)	15.33±5.50
September (2001)	85	48.67±3.14	20.00±2.16	(46.6+53.42)	15.67±1.76
	Harvested	67.00±13.19	19.67±2.59	(35.3+64.67)	19.33±0.72
Harvested on 18 to 25 September, 2001					

Table 15 Analysis of variance of live burrows of rodents at different age of fodder maize (*Zea mays*)

Source	d.f.	M.S.	F-ratio	CD (5%)	C.V.
Early sown fields					
Replicates	2	275.389	4.61		
A	2	444.056	7.43	5.236	
B	5	519.511	8.70	7.405	
AB	10	144.033	2.41	12.825	
Error	34	59.742			61.02
Late sown fields					
Replicates	2	580.155	7.98		
A	2	3607.822	49.64	6.379	
B	4	1150.978	15.84	8.236	
AB	8	184.545	2.54	14.265	
Error	28	72.679			39.67

- d.f. = Degree of freedom
M.S. = Mean square
CD = Critical difference
C.V. = Coefficient of variations
A = Factors (live burrow of *B. bangalensis*, *M. booduga* and new burrow digging activity)
B = Age (Days after sowing)

However, trappable population of *M. booduga* was more than *B. bengalensis* in berseem as compared to reverse conditions in fodder maize. Both the species are the major rodent pests of cereal crops, vegetables and sugarcane fields in Punjab (Parshad *et al* 1986, Parshad 1999). The fields selected for the present studies were mainly in the irrigated region and there was no sandy and unirrigated patch which explains the absence of xeric species like *Tatera indica* in fodder fields. The predominance of *B. bengalensis* in fodder fields also relates to extensive irrigation as the previous studies showed that this species prefers to live in wet soil conditions (Chakraborty 1992). The timing and location of colonising in the fodder fields were different for both the rodent species as *B. bengalensis* colonises the field boundaries/peripheral bunds at 25 and 40 DAS in berseem and fodder maize, respectively whereas, *M. booduga* colonise the field boundaries at 130 DAS in berseem and 40 DAS in fodder maize. However, trapping of few *M. booduga* at 30 DAS in berseem may be due to their visit from the adjoining fallow lands. Previous study in Belgium showed that *M. natalensis* were captured in maize field at 7 DAS (Leirs *et al* 1997) whereas, in present study *B. bengalensis* were trapped at 30 DAS in berseem and fodder maize fields. Small size fodder fields surrounded by fields of other crops like wheat from November-December onwards and of rice around fodder maize fields from May-June onwards along with fallow lands and dikes constitute a field mosaic in which the rodent populations are not separated from each other as indicated by trapping of few specimens at early crop stages.

The trapping and TMA of rodents at the earlier stages of crop when sufficient burrows did not develop in the fodder fields revealed the movement of rodents from the adjoining fields to the fodder fields. Unlike, *M. natalensis* in maize fields in Belgium (Leirs *et al* 1997), *R. rattus* avoided foraging at early vegetative stage of paddy in Indonesia (Yabe *et al* 2001). During the present studies, the activities related to feeding and burrowing were recorded only at 25 DAS in berseem and 40 DAS in fodder maize. This observation clearly shows that rodents persisted at field peripheries and avoided to visit at the earlier stages of fodder crops similar to *R. rattus* (Yabe *et al* 2001).

Temporal fluctuations in the rodent populations as revealed by trapping, TMC and live burrow count (LBC) at different stages of berseem and fodder maize may relate to different biotic and abiotic factors. Previous studies have shown that availability of food and shelter from the crop fields effect the abundance of rodents in the fields (Leirs *et al* 1993, Parshad 1999). However, berseem unlike the cereals, sugarcane and tree plantation crops is harvested 6-7 times within seven months of crop period and the fields are frequently irrigated at 7 to 15 days interval. These practices drastically effect the colonisation and activities of rodents in berseem fields as indicated by highly significant variations in the trapping, TMA and LBC data. Comparison of the data of three methods revealed that *B. bengalensis* persists at the periphery of the fields and establish with in fields at 40 DAS. Whereas, *M. booduga* which was absent at the peripheries of fields at earlier stages of the crops, visited from nearby fallow fields

and fields of other crops at 15-30 DAS, but actually established its burrows after 130 and 40 DAS in berseem and fodder maize crops respectively.

Small size fields of berseem are often surrounded by wheat fields which is a major winter (*Rabi*) crop in Punjab. Availability of food and shelter in this crop drastically effects the colonisation and activities of rodents in berseem as food and shelter was in plenty in wheat fields during the months of February to April. Trapping, TMA and LBC decline considerably and became zero in April and May. Farmers retain small sized fields of berseem for seed purposes and this period coincide maturity and harvesting of wheat in vicinities and that explains the absence of rodent activities in the fields of berseem at maturity. The changes in crop phenology are closely linked to seasonal changes in temperature, light and precipitations. December (7.8°C) and January (5.7°C) are cold months with low night temperature and surprisingly the activities of *B. bengalensis* are more during these months than those in other months of the crop season. Whereas, the burrowing activities of *M booduga* began in the month of February and did not establish in berseem field during winter months. However, rodents visited them from the adjoining areas. These observations clearly shown that both species respond differently to the environmental conditions related to temperature and irrigation and also to the availability of food from berseem fields.

Fodder maize is harvested between 85 to 100 DAS and thus provide good food and shelter to rodents at 40 DAS. The rodents once established within the crop fields continued to persist in the fodder maize fields unlike the maturity

stages of berseem crops as revealed by the trapping, TMA and LBC data. The small sized fields of fodder maize used in present studies were surrounded by rice and sugarcane. Fodder fields as compared to adjoining fields at different growth stages had high rodent population due to frequent waves of rodent immigration as a result of heavy rainfall and flooding in the adjoining fields and similar high rodent immigration was also reported in sugarcane fields as compare to adjoining fields (Parshad *et al* 1986).

4.2 FOOD AND FEEDING ECOLOGY

4.2.1 Stomach contents

4.2.1.1 Stomach content analysis of *B. bengalensis* captured from berseem fields

Rats were collected for their stomach content analyses from the berseem field where in addition to the crop plants some weeds namely *Rumex maritimus*, *C. intybus* and *M. denticulata* were also found at all stages of the crop. *B. compestris* var. *sarsoan* plants were also present in berseem fields before first cutting of berseem crop. Microscopic analysis of stomach contents of ten *B. bengalensis* captured dead with ST showed that the rats feed mainly on plant materials derived from berseem and other weed plants (Table 16). Rats captured live with SRT and anaesthetized with chloroform in the laboratory to take out their stomachs were found having only cracked wheat in their stomach content and thus were not consider for stomach content analyses. Although the stomach of rats had variable amount of food derived from berseem and three weed plants, but on the whole, berseem was predominated. The per cent number of rats which had parts of

berseem, *B. compestris*, *M. denticulata*, *C. intybus*, and *R. maritimus* in the stomachs was 100, 60, 20, 70 and 40 respectively. Results of identification of different plant materials and frequencies of their occurrence in the stomachs of rats collected from berseem at different stages (days after sowing, DAS) of the crop are summarised in table 17, which clearly show that rats had a number of food types in their stomachs which include parts of berseem, sarsoan and weeds of three different species which were the major food items available to *B. bengalensis* in the crop. Except maina (*M. denticulata*) whose leaves were present only in stomach of rats captured at 45 DAS in December, other weed plants were present in stomachs of rats captured at 30 DAS in November and at 45 DAS in December. The frequency of food derived from berseem was several times more than from weeds. At 30 and 45 DAS, rats also ingested considerable proportion of stems and leaves of *B. compestris* which is harvested by 30-35 DAS. It was not seen in the stomach contents of rats captured after 45 DAS (Table 17).

The unidentified material was mainly non-diagnostic parenchyma, collenchyma and sclerenchyma. The predominance of food derived from berseem plants in the stomachs of rats apparently related to their abundance availability in the berseem fields.

The rats preferred to eat the stem portion of the berseem plants as the stomach content had significantly higher proportion of pieces of stems than of leaves and roots. They showed least preferences for roots. Unlike that of berseem rats preferred to eat leaf portion of *B. compestris* and other weeds (Table 17).

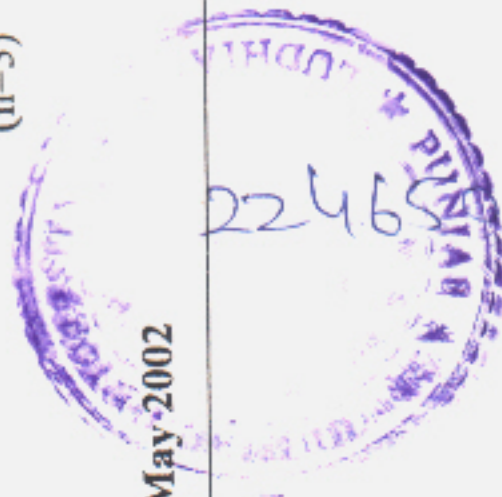
Table 16 Number of *Bandicota bengalensis* from berseem field with different food items

Food items	Number of rats (n=10)	Per cent
Trifolium alexanderium	10	100.0
Rumex maritimus	4	40.0
Medicago denticulata	2	20.0
Cichorium intybus	7	70.0
Brassica compestris var. sarson	6	60.0
<i>Unidentifiable</i>	10	100.0

Table 17 Microscopic stomach content analysis of *Bandicota bengalensis* collected from berseem field

Month	Days after sowing (DAS)	Number of fragments/ rat (slides x fragments)	Mean body weight mean±S.E.	Parts of plant	Percent frequency of occurrence of plant items (Mean±S.E.)							
					Berseem (<i>Trifolium alexandrinum</i>)	Sarsoan (<i>Brassica campestris</i>)	Janglipalak (<i>Rumex maritimus</i> Linn.)	Kashni (<i>Cichorium intybus</i> Linn.)	Maina (<i>Medicago denticulata</i> Willd.)	Unidentified		
Date of sowing - 15 October, 2001												
November (2001)	30	5x20	226.7±9.8 (n=3)	Roots	1.00±0.82	-	1.00±0.82	-	-	-	49.33±3.31	
				Stems	9.33±2.76	9.33±5.04	2.00±1.25	1.33±1.08	-	-		
				Leaves	9.67±2.84	10.33±2.76	3.33±0.27	3.00±1.71	-	-		
December (2001)	45	5 x 20	205.0±4.3 (n=4)	Roots	4.25±1.52	-	-	0.75±0.65	-	-	57.25±4.02	
				Stems	20.50±3.82	0.50±0.43	-	1.25±0.82	-	-		
				Leaves	6.50±2.28	3.25±2.04	1.00±0.87	1.50±1.29	2.25±1.24	-		
January (2002)	80	5 x 20	197.5±4.2 (n=3)	Roots	4.00±1.63	-	-	-	-	-	52.67±2.37	
				Stems	27.33±0.54	-	-	-	-	-		
				Leaves	18.00±2.49	-	-	2.0±0.9	0.66±0.54	-		

Harvested on 27 May 2002



Bulk of the stomach contents was constituted by unidentifiable plant materials.

4.2.1.2 Stomach-content analysis of *B. bengalensis* captured from fodder maize fields

Fodder maize fields had three major weeds namely *P. minima*, *E. hirta* and *E. aegyptiacum* at all stages of the crop. Bajra (*Pennisetum typhoides* L.) was also present at the border of crop fields. Stomach contents of ten *B. bengalensis* captured by ST were examined. Microscopic examination of stomach contents revealed both animal and plant materials in the stomachs of rats collected from fodder maize (Tables 18, 19). Animal material was represented by fragments of snail shells, earthworms and insect larvae. Their species identification was not possible. Animal material was recorded in the stomachs of 5 out of 10 rats examined. Of these 5 rats, only 1 rat (10%) had ingested insect larvae, two each (20%) had ingested parts of snail shell and earthworm (20%) in early sown crop field (Table 18). Microscopic analysis of the stomach contents revealed bulk of unidentifiable plant material. The fragments of plant material which could be identified were derived from stems, leaves and flower parts of fodder maize and bajra plants except in one rat where the stomach had few fragments of roots of cherry plant (*P. minima*). Dodhak and Madhana weeds occurred in fodder maize fields, but could not be detected in stomach contents of rats (Table 19). The results of present studies showed that rats in fodder maize, feed on parts of stems, leaves and mainly the immature floral parts of fodder maize and bajra near harvesting stage of the crop.

Table 18 Number of *Bandicota bengalensis* captured from fodder maize fields with different food items

Food items	Number of rats (n=10)	Per cent
<i>Animal material</i>		
<i>Insect larvae</i>	1	10.0
<i>Snail shell</i>	2	20.0
<i>Earthworm</i>	2	20.0
<i>Plant material</i>		
<i>Zea mays (Fodder maize)</i>	5	50.0
<i>Physalis minima (cherry)</i>	1	10.0
<i>Euphorpia hirta (Dodhak)</i>	0	0.0
<i>Eleusine aegyptiacum (Madhana)</i>	0	0.0
<i>Pennisetum typhoides (Bajra)</i>	5	50.0
<i>Immature cob</i>	3	30.0
<i>Unidentifiable</i>	10	100.0

Table 19 Microscopic stomach content analysis of *Bandicota bengalensis* collected from fodder maize fields

Month	Days after sowing (DAS)	Number of fragments/ rat (slides x fragments)	Mean body weight (n = no. of rats)*	Parts of plant	Percent frequency of occurrence of plant items (Mean±S.E.)						
					Foddermaize (<i>Zea mays</i>)	Cherry (<i>Physalis minima</i> L.)	Dodhak (<i>Euphorbia hirta</i> Linn.)	Madhana (<i>Eleusine aegyptiacum</i> Desf.)	Bajra (<i>Pennisetum typhoides</i> L.)	Unidentified	
Date of sowing - 7 June 2001 (Early sown crop)											
Early sown fodder maize											
July (2001)	30	5x20	220±21.2 (n=2)	Roots	-	2.00±1.41	-	-	-	3.00±0.71	-
				Stems	9.50±4.60	-	-	-	-	9.00±1.41	48.50±7.46
				Leaves	3.50±0.35	-	-	-	-	11.00±7.78	-
				Flowers	3.50±2.48	-	-	-	-	0.05±0.35	-
August (2001)	57	5 x 20	205±3.5 (n=2)	Roots	0.50±0.35	-	-	-	-	1.50±1.06	-
				Stems	3.00±2.12	-	-	-	-	9.00±0.71	49.50±1.06
				Leaves	13.05±0.35	-	-	-	-	8.00±2.83	-
				Flowers	17.50±8.84	-	-	-	-	-	-
Harvested on 21 August, 2001											
Date of sowing - 5 July 2001 (Late sown crop)											
Late sown fodder maize											
September (2001)	60	5 x 20	250±0.0 (n=1)	Roots	-	-	-	-	-	3.00±0.00	-
				Stems	-	-	-	-	-	12.00±0.00	38.00±0.00
				Leaves	4.00±0.00	-	-	-	-	-	-
				Flowers	18.00±0.00	-	-	-	-	17.00±0.00	-
Harvested on 24 September, 2001											

* Five rats out of 10 captured were having only animal material

The *B. bengalensis* is omnivorous and generalist in food choice, practically tasting whatever food is encountered in their natural habitat (Kamal and Khan 1977). Previous studies on stomach content analyses revealed that this specie feeds on a variety of materials like cereal grains, parts of roots, stems and leaves of crops and weed plants and grasses. The rats also ingest insect larvae, snails shells and crabs (Chakraboarty 1975, Kamal and Khan 1977). During the present studies, some rats ingested insect larvae, snails and earthworms when no grain or seed material was available to them for feeding within the field. Because of frequent cutting of berseem and non-availability of food from the fodder maize crop, rats primarily depend for feeding upon the plant materials derived from predominant plant community, i.e. berseem and fodder maize plants and other plants like : *B. compestris* in berseem and bajra plants in fodder maize fields. Rats preferably ate *M. denticulata* leaves in comparison to other major weeds in berseem field. The number of available foods, their taste and textural qualities were found to influence the feeding response of *B. bengalensis* (Malhi and Parshad 1994).

Apodemus agrarius preferred to eat maize plants especially at seedling stage of maize in Guizhou (Yang and Guo 1992). *Rattus nitidus* and *Mus* spp. may climb the maize plants to gain access to cob and species like *B. bengalensis*, *T. indica* and *Rattus meltada* cut the plants at the base to take at the cob parts (Parshad 1999). It is not clear whether *B. bengalensis* ingested the parts of immature cobs as recorded in the present studies, by cutting and felling the

maize plants or could access to cobs of plants trampled by some other animals.

4.3 RESPONSES OF RATS TOWARD BAITs IN LABORATORY

4.3.1 Laboratory experiments of choice feeding of cereal bait and plant materials from berseem crop fields

In addition to the crop plants, the berseem fields had three major weeds namely Janglipalak (*R. maritimus*), Kashni (*C. intybus*) and Maina (*M. denticulata*). The results of choice feeding experiments carried out by offering the cereal bait (cracked wheat grain, sugar and groundnut oil : WSO, 96:2:2) in choice to other plant material as source of food are given in table 20. The plant material constituted considerable proportion (33.1 to 58.4%) of the total daily food consumption of rats. However, marked variations were observed in the mean daily consumption of two foods offered to rats in choice in different experiments.

Both male and female *B. bengalensis* showed significantly ($P < 0.01$) more mean daily intake (MDI) of WSO bait than that of berseem plants and the differences in MDI of two foods were more in case of females who also ate significantly ($P < 0.01$) more of WSO than the males. Similarly, WSO bait was eaten non-significantly ($P < 0.01$) more than Jangli palak except that the males consumed significantly more of WSO than the Janglipalak. Unlike berseem, Janglipalak, Kashni and Maina was significantly more preferred by *B. bengalensis* as its MDI was significantly more ($P < 0.01$) than that of the WSO bait.

4.3.2 Laboratory experiments of choice feeding of cereal bait and plant material from fodder maize fields

The results of choice feeding experiments by offering fresh plant

Table 20 Feeding preferences of *Bandicota bengalensis* towards plant material of berseem field and WSO in bi-choice feeding test

Food combinations	Mean±S.E. Body weight (Sex)	Daily food consumption of <i>Bandicota bengalensis</i> (mean±S.E.), g/100 g body weight** (per cent acceptance)		
		WSO	Plant material	t-value
WSO vs berseem	246.67±21.26 (F)	8.01±0.28 (66.86)	3.97±0.32 (33.14)	19.296
	250.00±12.47 (M)	6.69±0.42 (53.86)	5.73±0.53 (46.14)	3.036
t-value		3.712	NS	
WSO v/s Janglipalak	250.00±18.86 (F)	8.19±0.26 (52.47)	7.42±0.57 (47.53)	NS
	253.00±16.99 (M)	9.19±0.59 (55.33)	7.4±0.6 (44.67)	3.866
t-value		2.334*	NS	
WSO v/sKashni	251.67±17.69 (F)	7.80±0.46 (54.70)	6.46±0.39 (45.30)	NS
	255.00±8.49 (M)	8.46±0.30 (54.83)	6.97±0.42 (45.17)	NS
t-value		NS	NS	
WSO v/s Maina	253.33±32.99 (F)	6.53±0.87 (45.54)	7.81±0.52 (54.46)	2.791
	256.66±11.86 (M)	5.96±0.20 (41.59)	8.37±0.53 (58.41)	5.986
t-value		1.835*	NS	

F = Female, M = Male

NS = Non-significant

WSO = (Cracked wheat : Sugar : Groundnut oil, 96:2:2)

** - Figures are the mean ± S.E. values of thirty observations (3 males x 3 females x 5 days)

* - Significant at P < 0.01

material of fodder maize (*Z. mays*), cherry (*P. minima*), Dodhak (*E. hirta*) and Madhana (*E. aegyptiacum*) in comparison to WSO are given in table 21. Both males and females showed significantly ($P < 0.01$) more consumption of WSO bait than plant materials. There were non-significant ($P > 0.01$) differences for the consumption of WSO between males and females. Females consumed more WSO than males, except cherry plants where males consumed more amount of cherry plant materials than by females, but the difference in consumptions was non-significant ($P < 0.01$) (Table 21).

The above laboratory bi-choice experiments have clearly shown that *B. bengalensis* use considerable amount of plant material in their diet. The importance of plant material in the diet of rodents, similar to *B. bengalensis*, has also been shown in *Microtus arvalis* (Balmelli *et al* 1999), *Apodemus* spp. (Abt and Bock 1998), *Neotoma megister* (Castleberry *et al* 2002) and *M. musculus* and *R. rattus* (Cole *et al* 2000). *B. bengalensis* consumed 5-9 g/100g body weight (b. wt.) of WSO when offered in choice with berseem, fodder maize and other weed plants. Apparently these results showed that most of the daily food requirements of *B. bengalensis* were from WSO. In addition rats consumed significant proportions of the plant material. WSO provides most of the energy requirements of rats and consumption of the plant material is related to their texture, water and sugar contents in addition to other nutrients like proteins and minerals. Earlier studies have shown the acceptance of *Trifolium platenase* and *Brassica napus* leaves by *M. arvalis* (Balmelli *et al* 1999). During the present

Table 21 Feeding preferences of *Bandicota bengalensis* towards plant material of fodder maize fields and WSO in bi-choice feeding test

Food combinations	Mean±S.E. Body weight (Sex)	Daily food consumption of <i>Bandicota bengalensis</i> (mean±S.E.), g/100 g body weight** (per cent acceptance)		
		WSO	Plant material	t-value
WSO vs fodder maize	200.00±4.70 (F)	7.63±0.54 (87.70)	1.07±0.19 (12.30)	11.460
	203.30±2.72 (M)	7.22±0.26 (84.15)	1.36±0.21 (15.85)	17.520
t-value		NS	NS	
WSO v/s Dodhak	206.00±2.72 (F)	6.40±0.29 (85.80)	1.06±0.22 (14.21)	11.790
	206.67±5.44 (M)	5.29±0.53 (77.23)	1.56±0.24 (22.77)	6.350
t-value		1.804*	NS	
WSO v/s Madhana	206.67±7.20 (F)	5.84±0.36 (72.82)	2.18±0.36 (27.18)	8.810
	210.00±4.71 (M)	5.46±0.29 (71.94)	2.13±0.20 (28.06)	4.250
t-value		NS	NS	
WSO v/s Cherry	210.00±4.71 (F)	6.65±0.34 (66.83)	3.30±0.17 (33.17)	8.710
	218.00±6.80 (M)	7.00±0.38 (72.77)	2.62±0.26 (27.23)	9.490
t-value		NS	2.243*	

F = Female, M = Male

NS = Non-significant

WSO = (Cracked wheat : Sugar : Groundnut oil, 96:2:2)

** - Figures are the mean ± S.E. values of thirty observations (3 males x 3 females x 5 days)

* - Significant at P < 0.01

studies, *B. bengalensis* consumed significantly ($P < 0.01$) more amount of maina weed than WSO mixture and non-significant by less amount of janglipalak and kashni whereas *T. alexandrium* was least preferred. Greater acceptance of maina over other plant materials in the presence of WSO might be related to its nutritive value.

In contrast to the plant materials from the berseem crop, the rats showed poor acceptance to plants and weeds from fodder maize crop. However, rats sampled and consumed considerable part of these plant materials, but they depended mainly on WSO mixture. Consumption of small proportion of less preferred food items by rodents seems to related to their general sampling behaviour and then rejecting the material after sampling (Cowan 1977, Barnett *et al* 1978, Parshad and Jindal 1991).

4.3.3 Field experiments of bait preferences by rodents in berseem crop

Comparative acceptance of two cereal baits (WMFSO, mixture of wheat flour, maize flour, sugar and groundnut oil; 48:48:2:2 and WSO, cracked wheat, sugar and groundnut oil; 96:2:2) offered in choice simultaneously at 20 sites/acre at different days after sowing of berseem are given in table 22. Percent sites showing consumption ranged from 10 to 45 for WMFSO and 25 to 70 for WSO. Rodents showed poor response to baits on 25 DAS and maximum at 40 DAS when the consumption of both the baits was maximum. Analysis of variance (Table 23) revealed significant variations ($P < 0.05$) due to age of the crop and non-significant differences between the consumption of two baits. However,

Table 22 Bait preferences of rodents in berseem (*Trifolium alexandrium*) field

Month	Age (DAS)	WMFSO (mean \pm S.E)	Percent sites showing consumption (n = 20)	WSO (mean \pm S.E)	Percent sites showing consumption (n = 20)	t-value*
Date of sowing - 21 October, 2001						
November (2001)	25	0.51 \pm 0.11	10	0.75 \pm 0.33	25	2.997 S
	40	3.95 \pm 1.34	45	5.45 \pm 1.36	70	0.764 NS
December (2001)	70	1.40 \pm 0.78	40	2.00 \pm 0.77	50	0.534 NS
January (2002)	100	1.35 \pm 0.65	40	0.35 \pm 0.15	25	1.506 NS
February (2002)	130	0.65 \pm 0.58	35	1.05 \pm 0.48	30	0.710 NS
March (2002)	160	0.30 \pm 0.12	25	0.40 \pm 0.13	35	0.540 NS

Harvested on 10 May 2002

WSO = (Cracked wheat : sugar: groundnut oil, 96:2:2)

WMFSO = (wheat flour : maize flour : sugar : groundnut oil, 48:48:2:2)

DAS = Days after sowing

* = t- value between mean consumption of WMFSO and WSO baits

Table 23 **Analysis of variance for bait preferences in berseem field**

Source	d.f.	M.S.	F-ratio	CD (5%)	C.V.
Replicates	19	11.207	1.12		
Between ages	5	108.387	10.86	1.40211	
Between WMFSO/WSO	1	8.067	0.81	NS	
Ages x WMFSO/WSO	5	6.667	0.67	NS	
Error	209	9.979			212.97

d.f. = Degree of freedom
M.S. = Mean square
CD = Critical difference
C.V. = Coefficient of variations
NS = Non-significant

comparison of bait consumption by student's t-test showed significantly more preferences for WSO than WMFSO on 25 DAS and non-significant differences at other stages (Table 22).

4.3.4 Field experiments of bait preferences by rodents in fodder maize

The results of bait preference experiments carried out in fodder maize fields by offering 20 g each of WMFSO and WSO in choice simultaneously at 20 sits/acre are shown in Table 24. Up to 45 DAS, there was no rodent activity in fodder maize fields as indicated by no response to cereal baits which were eaten at 60 DAS onwards when food consumption was evident at 100 per cent sites.

Bait consumption of WSO was significantly more in comparison to WMFSO at 90 and 120 DAS and was equal at 60 DAS. Analysis of variance (Table 25) revealed significant variations in food consumption at different stages of the crop

Variations in feeding responses of rodents to baits at different stages of berseem and fodder maize crop appear to be related to their relative abundance and activities at different stages of crops. Higher consumption between 40-70 DAS in berseem and between 60-120 DAS in fodder maize may be related to their burrowing and TMA during these periods. The preferences of WSO over WMFSO is indicated both in berseem and fodder maize crops. These observations reveal that addition of broken maize reduces palatability of baits. Previous studies on *B. bengalensis* have also shown that the cracked maize is avoided over the cracked form of wheat and other cereals (Parshad and Jindal 1991). Unlike *B. bengalensis*

Table 24 Bait preferences of rodents in fodder maize (*Zea mays*) fields

Month	Age (DAS)	WMFSO (mean \pm S.E)	(Percent sites accepted)	WSO (mean \pm S.E)	(Percent sites accepted)	t-value*
Date of sowing - 31 May, 2001						
June (2001)	15	0.00 \pm 0.00	0	0.00 \pm 0.00	0	00 -
	30	0.00 \pm 0.00	0	0.00 \pm 0.00	0	00 -
July (2001)	45	0.00 \pm 0.00	0	0.00 \pm 0.00	0	00 -
	60	18.10 \pm 0.84	100	18.95 \pm 0.34	100	0.919 NS
August (2001)	90	14.45 \pm 0.82	100	19.25 \pm 0.29	100	5.375 S
	September (2001)	120	17.50 \pm 0.91	100	19.60 \pm 0.18	100

Harvested on 31 September, 2001

WSO = (Cracked wheat : sugar: groundnut oil, 96:2:2)

WMFSO = (wheat flour : maize flour : sugar : groundnut oil, 48:48:2:2)

DAS = Days after sowing

*t - value between mean consumption of WMFSO and WSO baits

Table 25 Analysis of variance of two type of bait consumption in fodder maize (*Zea mays*)

Source	d.f.	M.S.	F-ratio	CD (5%)	C.V.
Replicates	19	6.4410290	1.58		
Between ages	5	3892.3980	956.09	0.8956	
Between WMFSO/WSO	1	100.10460	24.59	0.5170	
Ages x WMFSO/WSO	5	36.324010	8.92	1.2665	
Error	209	4.0711500			22.45

d.f. = Degree of freedom
M.S. = Mean square
CD = Critical difference
C.V. = Coefficient of variations

which avoids whole maize and cracked form of maize (Sridhara and Krishnamoorthy 1978), *R. rattus* preferred hulled maize (Wang and Wang 1997). Kamal and Khan (1977) showed more preferences of maize flour than cracked and whole maize grains.

4.4 CONTROL OF *BANDICOTA BENGALENSIS* IN FODDER FIELDS

4.4.1 Control of *B. bengalensis* in berseem fields

Application of 0.005% bromadiolone and 0.0375% racumin baits in three replicated fields of one acre each at the rate of 20 g/burrow of *B. bengalensis* resulted in 40.78% decrease in live burrow (LB) count with bromadiolone and 41.52% with racumin in comparison to 65.22% increase of LB in the untreated fields (Table 26). Despite of significant ($P < 0.05$) decrease in LB count with the rodenticides treatment, results of census bait consumption during post-census were almost similar to that in pre-census, indicating poor control success by census baiting method. These results showed that the methods of evaluating rodent control success yield variable results. Therefore changes in rodent activities in treated fields were also calculated with respect to corresponding changes in the reference fields (Henderson and Tilton 1955). Estimated percent control success with different methods of estimating control success varies. It has been found to be more with respect to reference field than with in the field values of rodent control success were low with census baiting than with LB count.

The possible explanation for these differences is that fodder field areas are small in size (each of about 1 acre) and the rats invade them frequently

Table 26 Efficacy of rodenticides baiting in berseem fields

Treatments	Census method	Pre-census	Post-census	Control success as percent reduction in rodent activity	
				Within field*	With respect to reference field**
0.005% bromadiolone	L.B./0.40 hectare	34.33	20.33	40.78	64.16
	WSO (g/400g)	374.67	368.33	1.69	22.51
0.0375% racumin	L.B./0.40 hectare	39.33	23.00	41.52	64.60
	WSO (g/400g)	303.33	284.33	6.26	26.12
Untreated (Reference)	L.B./0.40 hectare	34.50	57.00	-65.22	-
	WSO (g/400g)	312.50	396.50	-26.88	-

L.B. = Live burrow count

WSO = Cracked wheat : sugar : groundnut oil, 96:2:2

(-) represent increase in L.B. count and consumption of WSO

* - percent control success within field

** - percent mortality with respect to reference fields

$$\% \text{ control} = 100 - \frac{\text{Post-treatment census data}}{\text{Pretreatment census data}} \times 100$$

(Parshad 1987)

$$\% \text{ Mortality} = 100 \left(1 - \frac{t_2 \times r_1}{t_1 \times r_2} \right)$$

(Henderson and Tilton, 1955, EPPO, 1975)

t = Census bait intake from treated plot

r = Census bait intake from reference plot

t₁, r₁ = Pre-treatment census bait intakes

t₂, r₂ = Post-treatment census bait intakes

from the surrounding fields and may consume considerable amount of censes bait at the time of post-census.

4.4.2 Control of *Bandicota bengalensis* in fodder maize fields

The results of rodenticide (0.005% bromadiolone and 0.0375% racumin) treatments in three fields each, at the rate of 20g/burrow of *B. bengalensis* shown in Table 27. The rodenticide baiting resulted in 56.3 per cent decrease in LB count with bromadiolone and 56.4% with racumin. LB increased upto 79.7% in untreated control fields. LB count decreased significantly with rodenticide treatments, although WSO baiting census revealed poor control success. Similarly, as in case of berseem, methods of evaluating the success of rodent control yield variable results. These variations are due to fact that fodder field areas are small in size and rats can invade them from the surrounding fields. Previous studies showed that rodenticides, racumin (0.0375%) and bromadione (0.005%) are effective against rodents (Buckle 1994). Burrow baiting with racumin resulted in 50-70% control of *B. bengalensis* (Parshad and Malhi 1995). Continuous baiting with racumin bait for 10-12 days is required to achieve the higher level of control of *R. rattus* (Arora *et al* 1984). Feeding of ready-to-use racumin paste containing 0.0375%, coumatetralyl to *R. rattus* for 10 days in choice with WSO mix resulted in 90% mortality with medium lethal period of 5.55 days (Singla and Parshad 2002). During the present studies in both berseem and fodder maize treatment resulted in 41.52% and 56.37% control success. Such poor control success in comparison to cereal crops was also observed with burrow

Table 27 Efficiency of rodenticides baiting in foddermaize fields

Treatments	Census method	Pre-census	Post-census	Control success as percent reduction in rodent activity	
				Within field*	With respect to reference field**
0.005% bromadiolone	L.B./0.40 hectare	50.33	22.00	56.29	75.68
	WSO (g/400g)	356.33	314.67	11.69	19.26
0.0375% racumin	L.B./0.40 hectare	31.33	13.67	56.37	75.71
	WSO (g/400g)	364.33	340.00	6.67	14.68
Untreated (Reference)	L.B./0.40 hectare	34.50	62.00	-79.71	-
	WSO (g/400g)	362.50	396.50	-9.39	-

L.B. = Live burrow count

WSO = Cracked wheat : sugar : groundnut oil, 96:2:2

(-) represent increase in L.B. count and consumption of WSO

* - percent control success within field

** - percent mortality with respect to reference fields

$$\% \text{ control} = 100 - \frac{\text{Post-treatment census data}}{\text{Pretreatment census data}} \times 100$$

(Parshad 1987)

$$\% \text{ Mortality} = 100 \left(1 - \frac{t_2 \times r_1}{t_1 \times r_2} \right)$$

(Henderson and Tilton, 1955, EPPO, 1975)

t = Census bait intake from treated plot

r = Census bait intake from reference plot

t₁, r₁ = Pre-treatment census bait intakes

t₂, r₂ = Post-treatment census bait intakes

baiting of bromadiolone (0.005%) in fodder fields. Bromadiolone baiting resulted in 98-100% control of rodents (*B. bengalensis*, *R. rattus*, *T. indica*, *Meriones hurrianae*, *M. meltada* and *Mus* spp.) in rice, wheat, coconut, cocoa and oil palm in India (Mathur *et al* 1997) and 76.1% control in cauliflower and cabbage (Sheikher *et al* 1997). In the present studies burrow baiting with bromadiolone resulted in 40.78 and 56.29 per cent control success in berseem and fodder maize, respectively. This lesser control success in both fodder crops may be due to different agroecological conditions. Fodder fields, similar to that of sugarcane (Parshad *et al* 1986) may face several waves of rodent immigration from adjoining fields as a result of frequent disturbances in these due to ploughing, harvesting and flooding of fields with irrigation and rainfall. Rodents also enter the fields from fallow land that effect on the evaluation of control success by bait (WSO) census. Differences in the control success of two crops may be because of more irrigation in berseem fields than in fodder maize fields.

Chapter - V

SUMMARY

In the present studies, changes in population of rodents during crop season of berseem (*Trifolium alexandrium*) and fodder maize (*Zea mays*) were studied by track marking (TMC), trapping (TC) and live burrow count (LBC) census methods at farmers fields of village Dakha and in the fields of Punjab Agricultural University (PAU), Ludhiana. Rodents trapped during present studies were mainly represented by lesser bandicoot rat, *Bandicota bengalensis*, field mouse, *Mus booduga*, and few *Funambulus pennantii* and *Suncus murinus* in both the fodder crops. Species-specific differences were also observed in the trappability of single rat trap (SRT) and snap trap (ST) for *B. bengalensis* and *M. booduga*. The *B. bengalensis* which generally weighed above 200 g body weight were trapped and killed by ST whereas *M. booduga* which weighed about 10-15 g were mainly trapped live in SRT. Sex ratio of trapped female to male *B. bengalensis* was 1:1.6 in berseem and 1:2.75 in fodder maize fields. Both crops were frequently irrigated at 7-15 days intervals which drastically affected the colonisation and activities of rodents in berseem and fodder maize fields. During the present studies, activities related to feeding and burrowing were recorded at 25 days after sowing (DAS) in berseem and at 40 DAS in fodder maize fields. TMC data for *B. bengalensis* at earlier stages of fodder crop fields in which the rodents had not yet colonised as indicated by the absence of burrows, revealed the

movements of rodents to fodder fields from the adjoining fields of other crops. Experimental fields of berseem crop were surrounded by wheat crop and of fodder maize by rice crop. Agronomic practices such as ploughing, sowing, irrigation and harvesting in wheat and rice fields along with temperature, crop stage, irrigation and harvesting of the experimental fields affected the colonisation and activities of rodents in berseem and fodder maize fields. *B. bengalensis* were trapped more from November to January and *M. booduga* in March in berseem field. In fodder maize fields, rodent infestation regularly increased from 40 DAS upto maturity stages (70-95 DAS).

Bait preference studies using WMFSO (Wheat flour : maize flour : sugar : groundnut oil, 48 : 48 : 2 : 2) and WSO (cracked wheat : sugar : groundnut oil, 96 : 2 : 2) showed that rodents preferred WSO bait more than WMFSO bait in both the fodder crops. WSO was also preferred by *B. bengalensis* in choice to plant material such as berseem, fodder maize and other weeds present within these fields as determined in bi-choice feeding experiments under laboratory conditions. Therefore, WSO bait was considered suitable for preparation of rodenticide (bromadiolone 0.005% and racumin 0.0375%) baits for control of rodents in both the fodder fields.

The berseem crop had three major weeds namely *Rumex maritimus* Linn (janglipalak), *Cichorium intypus* Linn. (kashni) and *Medicago denticulata* Willd (maina). *Physalis minima* Linn. (cherry), *Euphorbia hirta* Linn. (dodhak) and *Eleusine aegyptiacum* Desf. (madhana) were the predominant weeds in

fodder maize fields. Except for maina, rats consumed significantly less amount of other weeds than WSO bait in bi-choice feeding tests. These laboratory experiments showed that although plant materials from weeds and crop plants are eaten by *B. bengalensis* in considerable amount in fields, but when available in choice to cereal food, the cereal was more preferred except in case of maina.

Few *B. bengalensis* caught from fodder-maize crops had ingested insect larvae, snails shells, earthworms, and immature cobs at the maturity stages as identified during microscopic examination of stomach contents.

Microscopic analysis of stomach contents of 10 rats, each collected dead by ST from berseem and fodder maize fields showed that in fields, rats mainly eat the plant material, most parts of which could not be identified (38-57%). On the basis of comparison of anatomical and cellular features of the food particles from the stomachs of rats with that of plant material from the fodder crops, it was found that rats primarily depended for feeding upon the plant materials derived from predominant plant community that is berseem and fodder maize plants and other plants like, *Brassica compestris* var. *sarsoan* before first cutting of berseem. Bajra (*Pennisetum typhoides* Linn.) and cherry plants formed important part of the diet of rats in fodder maize fields. Rats also consumed leaves of maina, jangli palak and kashni plant parts in berseem fields. The rats in fodder maize fields fed on parts of stems, roots, leaves and immature floral parts of fodder maize and bajra near harvesting stage of the crop.

Control success determined on the basis of census bait consumption

was much low than by live burrow count method. Calculations of control success by taking changes after treatment within the same field was less than by comparing with changes in the reference fields in which there was corresponding increase in rodent activities. Compared to about 65% increase in live burrows in reference fields, 40.78 and 41.52% reduction in live-burrows in berseem fields occurred after baiting with 0.005% bromadiolone and 0.0375% racumin respectively. Similarly these rodenticide treatments resulted in about 56.29 and 56.37% reduction in live burrows (with corresponding 79.7% increase in reference fields) in fodder maize fields with 0.005% bromadiolone and 0.0375% racumin, respectively. Low values of control success on the basis of pre and post-treatment WSO bait consumption may be due to post-treatment changes in rodent activities due to agronomic operations in surrounding fields of other crops

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