ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

COMMON MOLE_RAT, *Tachyoryctes splendens* (Ruppell, 1836) DISTRIBUTION AND ITS IMPACTS IN AGRICULTURAL FIELDS IN ANGECHA, CENTERAL ETHIOPIA

By

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A Thesis Submitted to the School of Graduate Studies Addis Ababa UniversityIn Partial Fulfillment of the Requirement for the Degree of Master of Science in Biology

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June, 2006

Acknowledgement

I am indebted to my advisor, Professor Afework Bekele in materializing this thesis work. Without his unreserved, not only instructive, but fatherly follow-up, advice and provision of all necessary equipment, it might not have been finalized. In addition, commenting on the draft document and provision of reference materials are appreciated.

I would like to extend my gratitude to Angacha Agriculture Rural Development (ARD) Officers, particularly to Ermias Ertiro whose efforts were high in initiating this work in the district. He also assisted me in data collection. I feel honored to thank my sisters, Eniyie, and Shagie and her husband Markos for their help during the study period.

I also acknowledge Dr. Dawit Abate for his timely effective facilitation and provision of the needed materials, Dr. Gurja Belay for his advice during my study period and all the department members for various helps on my requests. The Biology Department and School of Graduate Studies are greatly acknowledged for funding the project.

I am grateful to staff members of the Ayer Tena Senior Secondary School, especially those of the Biology Department for their cooperation in my absence and adjustment of program whenever it is not suited to my schedule. My appreciation and thanks are also extended to Ato Degello who provided me the map of study sites and Dr. Berhanu Matthews for reading the draft.

My deepest gratitude and appreciation go to my wife, Alemnesh Adgeh for her patience and understanding when she was forced to run family and social affairs in my absence at home during this study period.

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ABSTRACT

This study deals with the current distribution, abundance and impacts of mole rats in agricultural fields in Angacha. It was carried out from August 2005 to April 2006 covering the wet and dry seasons. The mole rat is the main rodent pest on Enset and potatoes in Angacha though its effect is minor in other crops. Direct total count was carried out from fresh surface signs (mounds) to estimate abundance and distribution of mole rats. Vector gopher traps and conical "Yeshibowotimed" were set to serve as snap and live traps. Stomach content analysis was carried out to determine food content of mole rat. These were applied in randomly selected four sites representing the "Dega" and "Woina-dega" climatic zones. Total counts using traps by digging and "Yeshibo-wotimed" catches depicted that "Dega" climatic zone sites Ls and Sb have more mole rat population than the "Woina-dega" climatic zone sites An-01 and K. Sb harbored 15 individuals per ha while An-01 7 individuals. The male to female sex ratio was 2.1:1.0, which was statistically significant, but the variation is similar in all sites. Common mole rats preferred open grasslands adjacent to crop fields and extend their foraging tunnels to nearby crop fields that are not far away. Fertile, well-drained soil and richness of food resources are the main factors for reduction in the length of burrow system ranging from 10.2 – 18.6 m. Although the animal minimizes expenditure of energy for burrowing in areas of food resources, the bolthole is long to protect itself from danger. Loss on Enset plantation is about 12% for the whole district. This is high where the plant requires 5 to 7 years to mature for food processing. This loss in such densely populated, with large family size and reduced farmland is high. Devising proper control and sustainable management on major and economically important rodent pest on Enset is crucial.

Key Words: Mole Rat, *Tachyoryctes splendens*, Agricultural fields, pest, Enset,

1. INTRODUCTION

The East African common mole rats, *Tachyoryctes splendens* belong to the mammalian Order Rodentia. The systematic position of mole rats is not well established. Since they are cryptic and require further investigation.

According to Nowak (1999), the total number of species in the genus *Tachyoryctes* is not clearly known. Allen (1939); Baskevich, et al. (1993) and (Ellerman 1941 cited in Baskevich, *et al*. 1993) considered *Tachyoryctes splendens* as one of the 14 species of the genus *Tachyoryctes*. Ellerman (1941) placed it in the Family *Muridae* while Allen (1939), Baskevich, et al., (1993) and Kingdon (1974) grouped it in the family *Rhizomyidae*.

Formerly, naming of species was based upon colour and geographical variations (Yalden, 1972; Greaves, 1989). But, Yalden (1975) and Yalden et al. (1976) lumped up the East African common mole rats as a single species except *Tachyoryctes macrocephalus*. However, Kingdon, (1997) recognized 11 species of the genus *Tachyoryctes* in the Family *Rhizomyidae.* Recently many taxonomists agree to include two species in the genus *Tachyoryctes:* the widespread, *T. splendens* and the larger, *T. macrocephalus* which is confined only to the Bale Mountains of Ethiopia (Yalden, et al., 1976).

The common mole rats, *T. splendens* is distributed throughout the highlands of Ethiopia, Central and Eastern Africa from Ethiopia as far as Eastern Zaire including parts of Somalia, Kenya, Rwanda, Burundi, Uganda and Northern Tanzania (Jarvis and Sale, 1971; Kingdon, 1997, Nowak, 1999). They inhabit from medium to high altitudes (Rahm, 1969). Common mole rats prefer open habitats like grasslands, wooded savanna with scattered trees and cultivated areas with loose soil. In Ethiopia, they occur at altitudes ranging from 1300 to above 4000 m asl in different regions (Yalden, et al., 1976; and Sewnet Mengistu and Afework Bekele, 2003). However, *T. macrocephalus* is confined only to the Bale Mountains (Yalden, 1985; Sillero-Zuberi et al., 1995).

Even though *T. splendens* is the least modified for fossorial life among the East African common mole rats, it constructs the burrow system consisting of multipurpose central nest, bolt-hole to retreat and numerous foraging tunnels (Jarvis and Sale, 1971). In the burrow system, the foraging tunnels may reach up to 52 m depending upon the availability of food. Molehills (soil mounds) are formed about 15-40 cm in diameter and 7-14 cm in height (Jarvis and Sale, 1971; Kingdon, 1974 and Nowak, 1999).

East African common mole rats mainly feed upon underground plant parts, roots, rhizomes, tubers, as well as stem bulbs and grasses. These are indiscriminately taken into underground hole (Bennett and Jarvis, 1995; Kingdon, 1997). Since the foraging tunnels of the common mole rats are usually just below the root levels, the animals always get fresh food (Jarvis and Sale, 1971; Sewnet Mengistu and Afwork Bekele, 2003). It also stores food at nesting chamber for adverse conditions. Although the usual foraging is through complex underground tunnels, it sometimes comes out to the surface in order to collect nesting materials and food.

The reproductive activity of the common mole rat is highest during the rainy seasons and lowest during the dry seasons. It is capable of breeding continuously throughout the year (Nowak, 1999). Females are polyestrus having 2 litters in successions. According to the study of Jarvis (1973) in Kenya, the average annual number of litters per female was 2.1 and gestation period was between 37- 40 days. In eastern Zaire, however, Rahm (1969) determined gestation to last from 46-49 days with 4 young per litter, but usually only 1 or 2. The East African common mole rat, *Tachyoryctes splendens* is fossorial, aggressive and solitary (Delany, 1986). Captured adults at Angacha were seen to fight savagely with each other. These did not show opposite sex behavioral attractions unlike the other mammals.

The present study area (Angacha) has a very dense human population that carry out mixed agriculture. Despite the dense cattle and human population and less crop output, pest mammals have been severely affecting the crop yield and grazing grasslands. One of these pests of agricultural crops is the East African common mole rat, ***T. splendens***. Angacha is known to harbor sizeable population of mole rats. It is the district's main pest feeding on Enset, potatoes, vegetables, pulses and grasses as well as cereals.

Rodent pests including mole rats cause about 30% and 20% of crop damage worldwide and Ethiopia, respectively (Afework Bekele and Leirs, 1997). For developing countries like Ethiopia with high population growth rate, periodically affected by drought and famine, such crop loss is paramount. To reduce this crop loss, proper control and sustainable management of pests should be given priority (Greaves, 1982 and Singleton, et al., 2003). The present study focuses on a rodent pest, the East African common mole rat, *Tachyoryctes splendens* that has an impact on agricultural fields. Therefore, the study aims at identifying the distribution and relative abundance of the common mole rat, to determine its pest status and impact on crop yields.

2. LITERATURE REVIEW

Ethiopia with variable altitudes, diversified climate, vegetation and landscape is rich in biodiversity. It is among the world's few countries that harbor unique characteristic flora and fauna with a high level of endemism (WCMC, 1992). Ethiopia inhabits about 277 species of mammals, of which 31 (11%) are endemic (Hillman, 1993). Among the Ethiopian mammal, 70 are rodents (Afework Bekele and Leirs, 1997).

Rodents are highly variable in morphology, habitat utilization, behavior, life history and distribution (Nedbal, et al., 1996). This diversity makes the taxonomic status of many rodent species uncertain (Delany and happold, 1979; Afework Bekele, 1986, 1995). According to Sewnet Mengistu and Afework Bekele (2003), there are still many species of rodents in Ethiopia whose systematic position is not well established.

The Order Rodentia consists of about 1750 species worldwide (Morris, 1965; Lynwood, 1994). This comprises 40% of the entire mammalian species (Meehan, 1984). Rodents are the most numerous and ubiquitous throughout the world, especially in Africa. The

East African rodents are grouped into 64 genera and 161 species (Lynwood, 1994). Among these, 70 species belong to Ethiopia in which 15 are endemic while the other 15 are believed to be economically important (Hillman, 1993).

The important role they play as a pest on crop plants and vector to human diseases make them economically and socially important (Delany, 1986). However, little is known about their biology to undertake appropriate control measures and sustainable management (Grant, et al., 1999). Ethiopia's annual crop yield loss by rodents is about 20% (Goodyear, 1976; Afework Bekele and Leirs, 1997). For such poor, repeatedly drought and famine-affected country, such crop loss is high. Therefore, proper rodent control measures and sustainable management activities should be devised (Singleton, et al., 2003; Lynwood, 1994).

The East African Common Mole rat, *T. splendens* is the least modified for fossorial life among the East African mole rats (Jarvis and Sale, 1971). Their external morphology is basically rat like, cylindrical with small eyes and ear pinnae, short limbs and tail, broad feet and large prominent incisors are modifications for underground life. The head-body length is 160 to 260 mm; tail length is 50 to 100 mm and weighs from 160 to 280g (Kingdon, 1974; Nowak, 1999). The other species in the family, *T. macrocephalus* is large in size. Its head-body length reaches about 313 mm and body weight ranges from 330 to 930 g (Nowak, 1999; Yalden, 1975). The short tail of *Tachyoryctes* is about twice the length of the hind feet and usually well haired (Nowak, 1999). The fur is thick and soft. In color and size, common mole rats are very variable. They can be black, brownish, reddish brown, pale gray, and cinnamon buff (Afework Bekele, 1986; Kingdon, 1974; Nowak, 1999; Yalden, 1976). Hence color variations are not used as taxonomic characteristics. The young are black in color. However, counter shading develops at advanced age. This counter shading disappears at old age in naked mole rats, which are eusocial colonial forms (Braude, 2000).

Morphological features by themselves may not be enough to identify and describe some species. Modern description and classification of species requires karyotype and DNA analysis. Analysis of karyotype number and karyotype morphology is important in the study of the biology and characterization of the species (Baskevich, *et al.*, 1993). However, Matthey, (1976) and Jotterand-Bellomo (1984) demonstrated that karyotype is a species characteristic as a rule. Despite this, karyotypes of subterranean, fossorial rodents exhibit greater diversity both between the species and within the species than most rodents (Nevo, 1979 and Nevo, *et al*., 1986). This view is not still accepted by some authors (George, 1979; Patton and Sherwood, 1983). Though there are controversies among authors on subterranean rodents especially on common mole rats, the karyotype study shows 2n = 48, but autosomal fundamental numbers (NFa) and centromere position of sex chromosomes are variable (Baskevich, et al., 1993; Ziyin Mihiretie, 2005).

For many mammals including rodents, subterranean burrows play an important role in interactions with the environment [(//H: http // kittlein tripod.com\ chapter-5 Population ecology of the subterranean rodents]. Burrows may be used as places of refuges and storage as well as nest sites (Carter and Encarnacao, 1983; Carter and Rosas, 1997). The construction, use and maintenance of the burrow are the central element to the subterranean species. Despite the assumptions that a subterranean lifestyle imposes similar selective pressures on mammalian inhabitants, regional variation in climate, soil and vegetation is considered important in generating adaptive differences among populations and species. As a result, convergent taxa may display different local adaptive peaks that reflect variation in local environment.

A critical issue for any species is the nature of “suitable habitats,” where the animals can live and reproduce. The subterranean rodents emerged during global aridization and emergence as an open country biota in the beginning of the mid-to late Cenozoic (Nevo, 1979). During the mid-to late Cenozoic Period, subterranean taxa extensively diversified occuring in open arid and/or semiarid habitats. With the exception of Rhizomys and Cannomys, which occur in bamboo thickets or forested areas of southeastern Asia, the present day subterranean rodents are found primarily in non-forested biomes such as grasslands, savannas, steppes and deserts. This tendency to occupy open habitats may in part reflect the nature of underground life.

Among the subterranean rodents, the East African common mole rats inhabit underground burrow system excavated by themselves (Jarvis and Sale, 1971). Burrow excavation is expensive in terms of energy. The energy costs of burrowing vary with the tunnel size and shape as well as soil features such as density and cohesiveness. Burrowing requires 360 - 400 times as much energy as moving similar distances across the surface (Vleck, 1979; Jarvis and Bennett, 1991). Burrow construction is an important component of the subterranean animal ecology to influence their distribution. It can limit their habitats.

Most subterranean rodents tend to live in porous soils or at least in well drained soils of poor water holding capacity (Brown and Hickman, 1973; Vleck, 1981; Reichman, *et al*., 1982; Cammeron, et al., 1988; Heth, 1989; Williams and Cameron, 1990; Antinuchi and Basch, 1992). This tendency reflects physical and energetic limitations on digging through wet soils as well as the physiological limitations imposed by the high partial pressure of CO_2 and low partial pressure of O_2, characteristic of subterranean burrows and soil depth.

When soil conditions are favorable, the absence of suitable vegetation may preclude occupation by subterranean rodents. As herbivores, these rodents feed extensively on vegetation. Appropriate plant species must be available to support the animals. In addition to providing food resources, the type of vegetation may determine the distribution through effects on patterns of ventilation. In particular, pattern of heat flux within subterranean burrows in turn determines whether a given habitat is suitable for underground existence. Thus, local distribution of any subterranean rodents is influenced by topography, soil and vegetation characteristics of the habitat. Since areas of suitable soil and vegetation are patchily distributed, individuals also tend to be spatially clumped (Busch, *et al.*, 1989). This is easily observed in *Tachyoryctes splendens* (Jarvis and Sale, 1971). However, *Ctenomys australis* that inhabits ecologically homogeneous sand dune has a relatively continuous local distribution (Zenuto and Basch, 1998).

The behavior used to excavate tunnels may in part determine the range of soil types in which burrows can be constructed. All subterranean rodents including *Tachyoryctes splendens* excavate burrows by shearing soil from the wall of tunnels, pushing the loose soil behind them, and then moving the soil through a lateral tunnel to the surface (Jarvis and Sale, 1971; Vleck, 1979). However, the specific behavior used to accomplish this task varies among species. Accordingly, Hildebrand (1985) identified three patterns of digging (scratch, chiseltoothe and head-lift) in different animals.

The burrow system of the subterranean mammals consists of numerous shallow foraging tunnels. It is frequently connected to a single deep (Miller, 1964) or shallow central chamber (Nevo, 1961; Jarvis and Sale, 1971; Hickman, 1979). The nest is used for nesting, food storage, sanitation, and bolthole to retreat (Jarvis and Sale, 1971). Foraging tunnels represent as much as 80-95% of the excavated burrow system (Jarvis and Bennett, 1991; Antinuchi and Busch, 1992; Heth, 1992). The pattern, extent and the depth of the burrow system components are variable not only among different geographical regions, but also even within the single locality. This variability is influenced by environmental factors like temperature, soil moisture and texture; vegetation cover and availability of food, altitude, and the number of individual animals per burrow system (Jarvis and Sale, 1971).

Food resources are important to both burrow location and burrow system size. This suggests that foraging is a critical component of the ecology of the subterranean rodents. The evolution of the subterranean rodents has been linked to a climatic shift towards warm and xeric conditions (Nevo, 1979). These conditions are also thought to have the evolution of the below ground storage organs in plants (Andersen, 1987). It is an adaptation that facilitated exploitation of the subterranean niches by providing locally abundant food stores that could be reached via underground tunnels. Since excavating tunnels to locate food is energetically expensive (Vleck, 1979,1981; Andersen and McMahon, 1981), subterranean rodents are food generalists whose diets contain a large proportion of the underground vegetation (Vleck, 1979).

In general, geophytes and other subterranean plant structures represent the majority of food items. The proportion of the diet of aerial plant structures tends to increase as the biomass of underground vegetation in the habitat decreases. Geophytes are the main food sources for *Bathyergidae and Spalacinae* mole rats. They inhabit arid regions in Africa and the Middle East (Lovegrove and Jarvis, 1986; Heth, *et al.,* 1989; Jarvis and Bennett, 1991). The highly social naked mole rat, *Hetrocephalus glaber* consumes subterranean tubers, bulbs and corms from a wide range of species of geophytes. Colony members cooperate to excavate tunnels leading to tubers (Jarvis, 1978). This cooperation allowed the *Heterocephalus glaber* to inhabit areas that are sparsely vegetated.

Members of the solitary bathyergid genera *Bathyergus* and *Georychus* include aerial plant parts in their diet. However, foraging occurs entirely below the ground. The animals feed by approaching plants from underneath and pulling vegetations down into the burrow (Davies and Jarvis, 1986). Foraging in *Tachyoryctes* is similar to that of *Heliophobius*. They feed upon wide range of roots and shoots searching through underground tunnels. They spend limited periods on the surface (Delany, 1986). The foraging tunnels are longitudinal with circular cross sections and diameter of 5 to 7 cm for *T. splendens*. It runs fairly at constant depth of 19 to 22 cm for *T. splendens* (Jarvis and Sale, 1971), 10 to 15 cm for *T. macrocephalus* (Yalden, 1975) and 8 to 20 cm for *Cryptomys* (Hickman, 1979). According to Jarvis and Sale (1971), the depth of foraging tunnels is regulated by root (rhizome) level of the plant on which the mole rats feed upon. Thus, depth of foraging tunnel varies depending on the position of the tunnels in relation to the nest (Hickman, 1979), breeding season and water level (Nevo, 1961). The total length of the foraging tunnels ranges from 58 to 340 m for *Cryptomys* (Hickman, 1979) and 18 to 52 m for *T. splendens.* This is determined by the availability of food, need of food and number of occupants (Jarvis and Sale, 1971). These tunnels are air tightly plugged to maintain temperature and protect them against predation.

The burrow system of mole rats contains either one functional nest for *Cryptomys* (Genelly, 1965; Hickman, 1979) and *T. splendens* (Jarvis and Sale, 1971) or accessory nest chambers may be present for *Spalax* (Nevo, 1961). The diameter of the nest chamber varies from species to species. The diameter of the nest chamber difference is related to the size, number of occupants and the function of the nest. The nest chamber is primarily a sleeping, resting and breeding site for *Cryptomys* (Hickman, 1979), and *Heterocephalus* and *Heliophobius* (Jarvis and Sale, 1971). *Spalax* builds nest during the breeding season only (Nevo, 1961). The East African common mole rats, *Tachyoryctes splendens* construct large, single, multipurpose nest for food storage, sleeping, sanitation as well as for breeding (Jarvis, 1973; Jarvis and Sale, 1971).

Mole rats, *T. splendens* and *Heliophobius* (Jarvis and Sale, 1971), and *Cryptomys* (Hickman, 1979) have a blind-ended tunnel, the bolthole at the deepest part of the burrow system. It is associated with the nest chamber of *T. splendens* (Jarvis and Sale, 1971). As the mole rat is alarmed, it retreats into this tunnel and plugs it in order to mislead the source of the alarm. Thus, bolthole serves as escaping tunnel from the danger (Jarvis and Sale, 1971). However, Hickman (1977) argued that the deep tunnel bolthole primarily functions to keep humidity high in the burrow system.

The distribution pattern of the East African mole rat, *Tachyoryctes splendens* is discontinuous ranging from Ethiopia and parts of Somalia as far as Eastern Zaire, Burundi and Northern Tanzania. They seldom occur in areas with less than 500 mm rainfall per annum, but they best established in wet uplands (Kingdon, 1974, 1997; Messonne, 1968; Nowak, 1999). Their distribution pattern varies and fluctuates seasonally based upon altitude and vegetation cover as well as precipitation of climatic factors. *Tachyoryctes* favors deep, well-drained, often-volcanic soils, rainfall over 510 mm a year and vegetation cover of grass to open forests (Jarvis and Sale, 1971). It occurs over a considerable altitude reaching a height of over 4000 m asl (Jarvis, 1973). Since it is a ubiquitous feeder, its habitats provide grass roots, rhizomes, stems and leaves, herbs, shrub and tree roots, tubers, bulbs and corms (Jarvis and Sale, 1971).

Population density for subterranean rodents like *T. splendens* tends to be lower than those of surface dwelling microtines and murid types. The density for surface dwelling species routinely reaches about 150 individuals per ha. In Microtine (Tamarin, 1977), density for subterranean species seldom exceeds 80 individuals per ha. This is considerably lower in Geomidae: (Ingles, 1952) and in Ctenomidae: (Pearson, 1959). However, there are exceptions with greater than 200 individuals per hectare in ***T. splendens*** (Jarvis, 1973), suggesting that *T. splendens* occurs in a very dense concentration. Low population density may arise in part due to the tendency of the subterranean species to be solitary. Each maintains its own exclusive-use of territory. The exclusive use areas are shared only by mothers and unweaned offsprings. But males and females share briefly during the breeding season (H://htm.\ Population Ecology of Subterranean Rodents htm. 2/12/2005). However, *Heterocephalus glaber* is a eusocial colonial species.

The ratio of adult males to females varies among the species of subterranean rodent populations. Female-biased ratios are observed for some solitary species like *Ctenomys talarum* (Malizia and Busch, 1991), *T. splendens* (Jarvis, 1973) and *Pappogeomys castanops* (William and Baker, 1976). In contrast, *Heterocephaus* is male biased (Brett, 1991; Genelly, 1965).

Age structure is highly related to patterns of reproduction, mortality and population growth. Among the subterranean rodents, high mortality and frequent migration of subadults generate adult-biased age structures. This assertion is supported by data from a number of subterranean rodent species. For example the age structure of *Ctenomys talarum* (Busch, et al., 1989), *Ctenomys australis* (Zenuto and Busch, 1998), *T. splendens* (Jarvis, 1973) were observed as 55%, 75%, and 66%, respectively. Thus, predominance of adults is typical feature of the population of the subterranean rodents.

Rahm (1969) examined nearly 10,000 female root rats and observed that gestation period ranges from 46 to 49 days, and pregnancy dropped to a minimum at the end of rainy season. Thus, the period of inactivity and retreat to deeper levels during the dry season has the effect of reducing contact and sexual behavior. Among the examined females, 58 % had one young, 38% had two, 2.2% had three and 1.1% had four. Embryo (Fetus) resorption had been noted in this species, serving to reduce the number of fetuses (Kingdon, 1974).

Dispersal is a fundamental component of demography that has a profound effect on the population dynamics, social behavior and genetic structure of populations. In general, dispersal rate for subterranean rodents is assumed to be low (Busch, *et al*., 1989). This assumption in addition to fossorial life makes the pattern of dispersal difficult in natural population. Direct quantification and characterization of individual movement has been limited to only a few species, *G. attwaterri*, (Williams and Cameron 1990), *C. talarum*, (Malizia *et al*., 1995) and *H. glaber*, (O'Riain *et al*., 1996). Among the small mammals, it is generally males that disperse (Greenwood, 1980). However, among subterranean rodents, dispersal of both sexes is relatively common and the primary dispersers are juveniles and subadults (Howard and Childs, 1959; Vaughan, 1962).

Rodent pests affect people in three ways: consume, spoil agricultural crops in the field and spoil stored food. They also act as reservoirs and vectors of diseases that affect the health of people and their stock (htm: 21/2/2006 Why study rodent populations). However, 33% of crops produced in U.S.A. and 35 % on a worldwide basis are lost due to pests (Pimentel, 1976). Afework Bekele and Leirs (2003) stated that rodent damage reached about 26.4% on maize fields in Ziway, Central Ethiopia. However, in East Africa, rodent pests typically consume about 10 to 15% of the field crops on a year-to-year basis (Http://users.Ugent.be\ Rodent pests of Somalia and their control. 27/05/2006). Crop yield loss by pest is variable. The protection of plants from pests is fundamental for food production. The needs of human society are in direct competition for resources with pest populations (Allen and Bath, 1980). Thus, the system requires proper control and sustainable management. This requires biological, chemical, environmental, genetic and cultural methods of pest control. This is recently known as Integrated Pest Management (IPM). Based on ecological, sociobiological and economic factors, rodent pests can be controlled and managed by trapping, using of rodenticides and fumigants, by habitat manipulation and by encouraging natural predators.

3. OBJECTIVES

3.1 General Objectives

- To study the distribution of mole rats and their impacts on agricultural fields in Angacha district.

3.2 Specific objectives

- To identify the distribution and relative abundance of mole rats in Angacha District.
- To investigate the ecology with emphasis on the burrow system and feeding habits of the species.
- To determine the pest status on economically important crop plants.
- To estimate yield loss in agricultural fields and grazing grasslands.
- To devise proper control and sustainable management of rodent pest, common mole rat population.

4. THE STUDY AREA

4.1 Geology and location of study area, Angacha

The proposed study area, Angacha district is located in the central part of Ethiopia. Angacha is located 260 km South of Addis Ababa. It lies between 07^{0}16’09N-07^{0}30’20N and 037^{0}45’48E-037^{0}51’34E. Its neighboring districts are Kedida-gemella to the east and southeast, Kecha-bira and Omo-sheleko districts to the south, Soro of Hadya to the west and Limu district of Hadya to the north (Fig. 1).

The altitude of the area ranges from 2100 to 3028 m asl. The highest peak is Mount Ambericho. The landscape of the area consists of 30% plain land, 65% rugged plateau and 5% cliff (Ambericho, 1997). Most of the area is known to have fertile loam soil, which is suitable for agricultural activities. Intensified mixed agricultural practices are prominent in this area (Fig. 2).

Figure 2. Physiography of the Study Area

(Photo Abebe K.)

4.2. Land-use and Climate

According to the District Officers' Rural Development information and SNNPRS, Hadiya-KT cluster health profile (2005), out of the 39,884.9 hectares, an estimated 30,484 ha is cultivated feeding over 200,000 human populations with a population density of 384 persons per km^2. About 1674.22 ha of land is used for cattle grazing that support over 196,832 households. Patchily managed enclosures to conserve the soil, wildlife and natural vegetation make up about 2210 hectares. Angacha district possesses numerous streams and rivers, which are the main water resources. However, seven of them, namely Ferekessa, Satamie, Aziga, Shappa, Adaygita are big rivers that drain to Lake Boyo in Hadiya.

The average annual precipitation ranges from 1230.6 mm to 2397 mm with mean annual precipitation of 1630.8 mm. The average minimum and maximum temperature ranges from 13.67^{0}C to 24.05^{0}C with the mean annual temperature of 20^{0}C (Figs. 3 and 4). The wet season is characterized by eight months of rainfall from March to October followed by the dry season that ranges from December to February. In general, the district belongs to "Dega" (cool) climatic zone (35%) with altitude above 2400m asl, temperature ranging from near freezing to 16^{0}C and rainfall 1200 – 1280 mm. The "Woina-dega" (Temperate) climatic zone (65%) with altitude between 1500 to 2400m asl, average annual temperature between 16^{0}C and 20^{0}C and annual rainfall 510 – 1100 mm (Ambericho, 1997). The farmland distribution area is less than 0.5 hectare per farmer. Ranching is also practiced even though the population density is high.

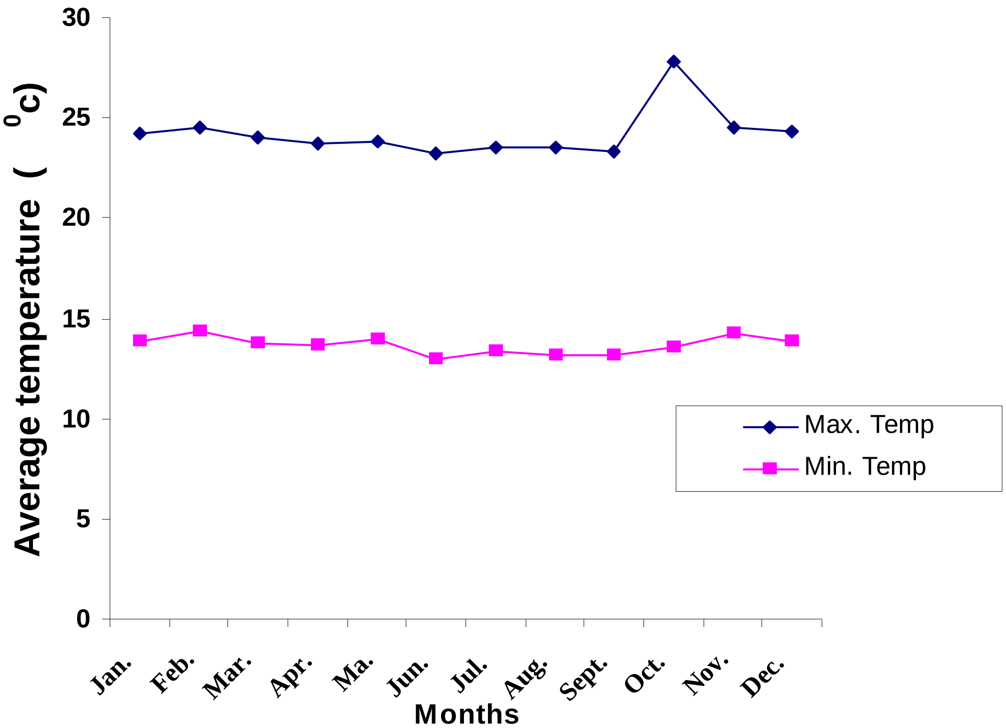


Figure 3. Monthly average maximum and minimum temperature of Angacha from 1994-2005 (Ethiopian Meteorology Agency)

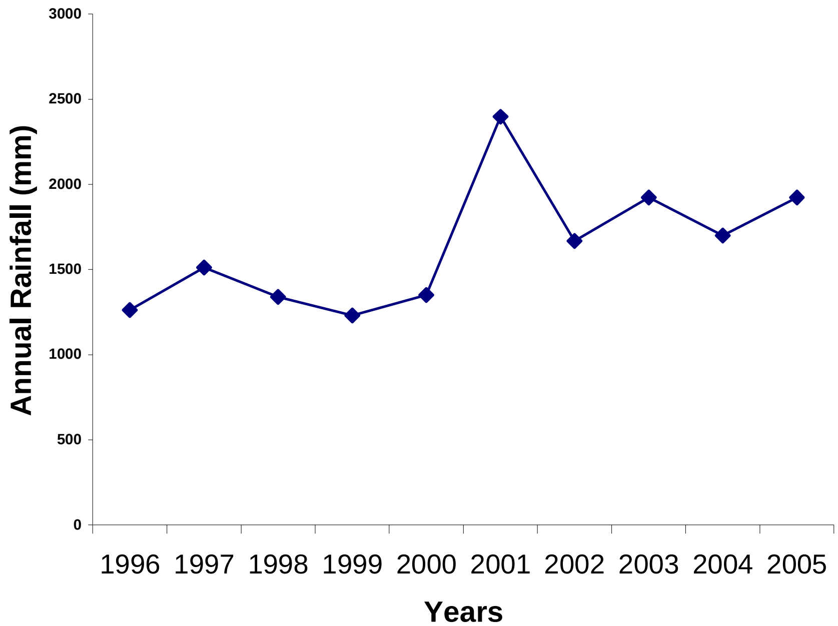


Figure 4. Mean annual rainfall of Angacha from 1996 – 2005 (Ethiopian Meteorology Agency)

4.3. Flora and Fauna

The flora and fauna of the district are not studied in detail. However, the dominant riverine vegetation includes *Podocarpus falcatus*, fig tree (*Ficus carica*), tid (*Juniperus procera*) and dense bushes. Recently, due to increased human population and the extended agricultural activities, Angacha has considerably depleted of natural vegetation. Deforestation of natural habitats resulted in loss of previously inhabiting wildlife populations like baboons, monkeys, leopard, civet, wildcat, etc. The process of devastation is continuing. The local people practice intensified mixed agricultural activities. The cultural practices remained primitive and at subsistence level, where crop yield is low to feed such a high population. Besides this, rodent pests reduce crop yield.

Among the rodent pests, the East African common mole rat, ***T. splendens*** is the most prominent economically important rodent pest of the district.

5. MATERIALS AND METHODS

5.1. Materials

The materials used to collect data are GPS, Camera, Dissecting kits, meter tape, balance, spade and axe. The Conical local trap made of Iron wire, string, “Hoficho” and wooden plug commonly known as “Yeshibo-Wotimed” was employed in trappings. This serves as live and snap traps (Fig. 5). The baits used were potato (*Solanum tuberosum*), garlic (*Allium ursinum*), besobilla (*Ocimum sanctum var anisatum*). Vector gopher traps were also used for trapping.

Figure 5. “Yeshibo-wotimed” set on trapping the common mole rat

(Photo Abebe K.)

5.2. Methods

The study covered both wet (August 2005 to October 2005) and dry (December 2005 to April 2006) seasons. Preliminary survey was carried out on the distribution of mole rats and damage incurred on agriculturally important crop plants in the beginning of August 20005.

The abundance, distribution and density of common mole rat, *T. Splendens* were estimated with direct total count from their territorial limits and mound signs on randomly selected farmers farmlands. The area comprised of 0.1 to 0.2 ha per crop field. Since snap trapping and burrowing were not employed to estimate the population density in grids unlike the other rodents, total counts were used from surface signs (mounds) (Shimelis Beyene, 1986; Sillerro-Zubirri, *et al*.1995). Traps and burrowing employed to investigate its ecology following Jarvis and Sale (1971).

Direct count on damaged crop plants and grazing grasses per plots was carried out to determine feeding habits and pest status of the common mole rats as well as its impact on agricultural fields in the district. In addition, local people were interviewed to get important information about the animal and to devise control mechanism.

Total count was carried out to investigate mole rat damage on Enset. The damaged Enset plants were counted for 10 to 12 days per month in both wet and dry seasons. From the damaged Enset plants, percentage losses were calculated per study sites and the income in birr for each locality. However, damage on potatoes, cereals and pulses were estimated in non-parametric method. Nevertheless, the hoarded potatoes in the mole rat nests were measured in kilogram per nest. The area covered by mole rat mounds was also measured using meters to estimate grass yield loss. Stomach content analysis was carried out to find food items of the animal. Stomach contents were washed by water, the effluents decanted, then settled residues examined to determine food items eaten in each locality.

5.2.1. Sampling design

Four investigation sites were randomly selected using the main road as a transect. Among the four sites, two sites were selected from “Dega” and the other two represented “Woina-dega” climatic zones. Lemi-suticho and Serara-bokata represented “Dega” climatic zone while Angacha-01 and Kerekicho, represented “Woina-Dega” climatic zone

As the distribution of common mole rats is discontinuous, grids and transect lines were not employed. However, direct soil mound counts and traps and burrow system excavation following Jarvis and Sale (1971) and Shimeles Beyene (1986) were carried out to investigate abundance, distribution and other ecological parameters. The procedure followed by Jarvis and Sale (1971) was burrow system excavation by using spade and axe with the help of assistants. The position of burrows, molehills, nests and food stores were plotted on graph paper. Nest materials, food stores and commensals were identified where possible.

Snap and Vector gopher traps were set and kept in selected study plots. Conical local traps (Yeshibo-wotimed) were also employed as snap and live traps. Morphometric measurements were recorded from the trapped and freshly killed mole rats. The morphometric measurements recorded were weight (W), total length (TL), head - body length (HB), tail length (T) and hind foot length (HF). Weight was recorded using Pesola spring balance to the nearest 1g. The trapped animals were sexed and the age was structured in the field by close observation on color, general size and reproductive conditions following Afework Bekele (1986). A total of 31 common mole rats were trapped from four different sites representing “Dega” and “Woina-Dega” climatic zones.

5.2.2. Data analyses

Depending on the results and variables, SPSS statistical packages were used to compute the relative distribution, abundance, pest status and the impact of *Tachyoryctes splendens* on agricultural fields in Angacha. Two factor ANOVA was employed to compute significance levels within and between sites and crop fields (habitats) for mole rat distribution and its impact.

6. RESULTS

The work comprises six components. All the six components of the results are sequentially presented to cover external body measurements, abundance and distribution, subterranean ecology of mole rat, population structure and impact of common mole rats on agricultural fields.

6. 1. External body measurements

A total of 31 specimens were captured by local trap "Yeshibo-wotimed" and burrowing from the four study sites though trapping the animal was not easy task (Table 1). Trapping by using vector gopher traps was not successful. Body measurements for trapped specimens are given in Table 2. The t – test for body measurements showed significant differences for body weight at Angacha-01 (An-01), Kerekicho (K), Lemi-suticho (Ls) and Serara-bokata (Sb) sites at $P< 0.01$ (Appendix III). The t - test ($t = 6.194$, $df = 4$, $p = 0.003$) for external characters revealed that the weight of populations of An-0 is significantly different from Sb at $P < 0.01$ followed by Ls at $P < 0.05$. However, there are no significant variations in the remaining four standard external measurements (Table 2).

Table 1. Sites, geographic position, altitude and number of specimen trapped.

Sites	Geographic position	Altitude in m asl.	Male	Female	Total
Angacha (An-01)	07^{0}21’20N 37^{0}51’48E	2262-2330	5	3	8
Kerekich (K)	07^{0}21’5E 37^{0}53’31E	2170-2270	7	3	10
Lemi-Suticho(Ls)	07^{0}18’14N 37^{0}53’31E	2675-2754	4	2	6
Serara-bokata (Sb)	0718’09N 37018’17E	2548 -2724	5	2	7
Total			21	10	31

Table 2. Mean and standard deviation for external body measurements (cm) of common mole rat from Angacha study sites.

Study sites	Body measurement				
	W	TL	HB	T	HF
Angacha (An-01)	278.0± 4.7	27±0	21	6	3
Kerekicho (K)	258.57±1.36	26.51±0.89	20.57±0.73	6.14±0.35	3
Lemi-suticho (Ls)	272.5±22.78	27.75±1.5	22±0.71	6.25±0.4	3
Serara-bokata (Sb)	220±5.77	26.16±5.77	20.67±0.73	5.83±0.37	3

6. 2. Population structure of common mole rats.

Out of 31-trapped specimens, 21 were males and 10 females. The sex ratio was significantly male biased (2.1:1). The age structure of the trapped mole rats shows 78.57% adult, 10.71% subadult and 10.71% juveniles (Table 3). The population structure analysis shows that there is significant difference in sex ratio and age structure at $P < 0.05$ and 0.01 ($t = 0.01$ and 0.006), respectively.

Table 3. Population structure of mole rats from four study sites (Angacha-01(An-01), Kerekicho (K), Lemi-suticho (Ls) and Serara-bokata (Sb)).

Study sites	sex		age			
	Male	Female	Adult	Subadult	Juvenile	Total
An-01	5	3	6	1	1	8
K	7	3	7	1	2	10
Ls	4	2	4	1	1	6
Sb	5	2	5	1	1	7
Total	21	10	22	4	5	31
Age %			78.57	10.71	10.71	

6. 3. Abundance and distribution of mole rats

Common mole rats were more abundant in the habitats (crop fields) of Serara-bokata (Sb) with a mean and SD of 4.5 ± 1 per plot and 15 individuals per ha followed by Lemi-suticho (Ls) with a mean and SD of 4.0 ± 0.75 and 12 individuals per ha. The least abundance and distribution were observed in habitats of Angacha-01 and Kerekicho.

Habitats of "Dega" climatic zones harbored more number of common mole rats than to "Woina-dega" climatic zones (Table 4).

Table 4. Abundance of common mole rats in the habitats among the different sites

Study sites	No. of plots (Crop fields)	Estimated population size	
		Mean ± SD/plot	Individuals / ha
An-01	10	3.0 ± 1.30	7
K	10	3.4 ± 1.44	10
Ls	8	4.0 ± 0.75	12
Sb	8	4.5 ± 1.00	15

Mole rats were not evenly distributed within the crop fields of the study sites (Table 5). The highest population density was observed during the wet season within the habitats of "Dega" climatic zone at sites Sb and Ls. Sb and Ls have the observed mean and SD 4.5 ± 1.12 and 4.25 ± 0.83 per plot, and 15 and 12 individuals per ha, respectively (Table 6). Despite this, Serara-bokata did not show seasonal variation in population density. The least mole rat population density was observed for "Woina-dega" climatic zone at sites An-01 and K for both wet and dry seasons. An-01 and K have the observed mean and SD 3.2 ± 1.17 and 3.8 ± 1.33 per plot, and 8 and 10 individuals per ha, respectively (Table 6).

The Two factors ANOVA showed that there were significant variations in population densities between the study sites at $P < 0.05$ ($F = 21$ & 24 $P = 0.016$ & $0{,}016$), respectively for both wet and dry seasons (Appendix I).

Density of mole rats was of the highest in grasslands followed by Enset during both seasons. Grasslands and Enset have 5.0 ± 0.71 and 4.25 ± 0.83 mole rats per plot and 12 and 10 individuals per ha, respectively. The least infested crop field was sugarcane with 3.0 ± 1.0 per plot and 4 individuals per ha (Table 7). Two factor ANOVA showed that there was significant variation between habitats at $P < 0.05$ ($F = 21$, $P = 0.02$ and $F = 18$, $P = 0.02$), respectively (Appendix I).

Table 5 Total count of mole rats from surface sign (mounds) in each crop fields of Angacha-01 (An-01), Kerekicho(K), Lemi-suticho (Ls) and Serera-bokata (Sb) at different seasons: (E = Enset, P = potato, Cp = cereals & pulses, Sc = sugarcane, G = grassland), - = not cultivated (grown).

Seasons	S.sites / Habitats	An-01	K	Ls	Sb	Total
	E	4	4	5	6	19
	P	2	3	4	3	12
Wet	Cp	3	2	3	4	12
	Sc	3	4	-	-	7
	G	5	5	4	5	19
	Total	17	18	16	18	69
	E	3	4	4	5	16
	P	2	2	5	3	12
Dry	Cp	3	3	2	4	12
	Sc	3	3	-	-	6
	G	4	5	3	5	17

Total	15	17	13	17	62

Table 6. Density of common mole rats in the study sites, Angacha (An-01), Kerekicho (K), Lemi-suticho (Ls) and Serara-bokata (Sb) during wet and dry seasons.

Study sites	Seasons	No. of habitats	Estimated population size	
			Mean ± SD/plot	Individuals/ha
Angacha-01 (An-01)	Wet	5	3.2 ± 1.17	8
	Dry	5	2.8 ± 0.75	7
Kerekicho (K)	Wet	5	3.8 ± 1.33	10
	Dry	5	3.4 ± 1.08	9
Lemi-suticho (Ls)	Wet	4	4.25 ± 0.83	12
	Dry	4	3.75 ± 1.09	10
Serara-bokata	Wet	4	4.5 ± 1.12	15

(Sb)				
	Dry	4	4.5 ± 0.5	12

Table 7. Density of common mole rats in crop fields (habitats) in Angacha-01 (An-01), Kerekicho (K), Lemi-suticho (Ls) and Serara-bokata (Sb) during wet and dry seasons.

Crop fields	Seasons	No. of study sites	Estimated population size	
			Mean ± SD/plot	Individuals/ha
Enset	Wet	4	4.75 ± 0.83	10
	Dry	4	4.0 ± 0.71	8
Potato	Wet	4	3.25 ±1.09	7
	Dry	4	3.25 ±1.3	7
Cereal & pulses	Wet	4	3.0 ± 0.71	6
	Dry	4	3.o ± 0.71	6
Sugarcane	Wet	2	3.0 ± 1.0	4
	Dry	2	2.5 ± 0.35	3

Grasslands	Wet	4	5.0 ± 0.71	12
	Dry	4	4.5 ± 0.5	12

6. 4. The burrow system and ecology of common mole rat

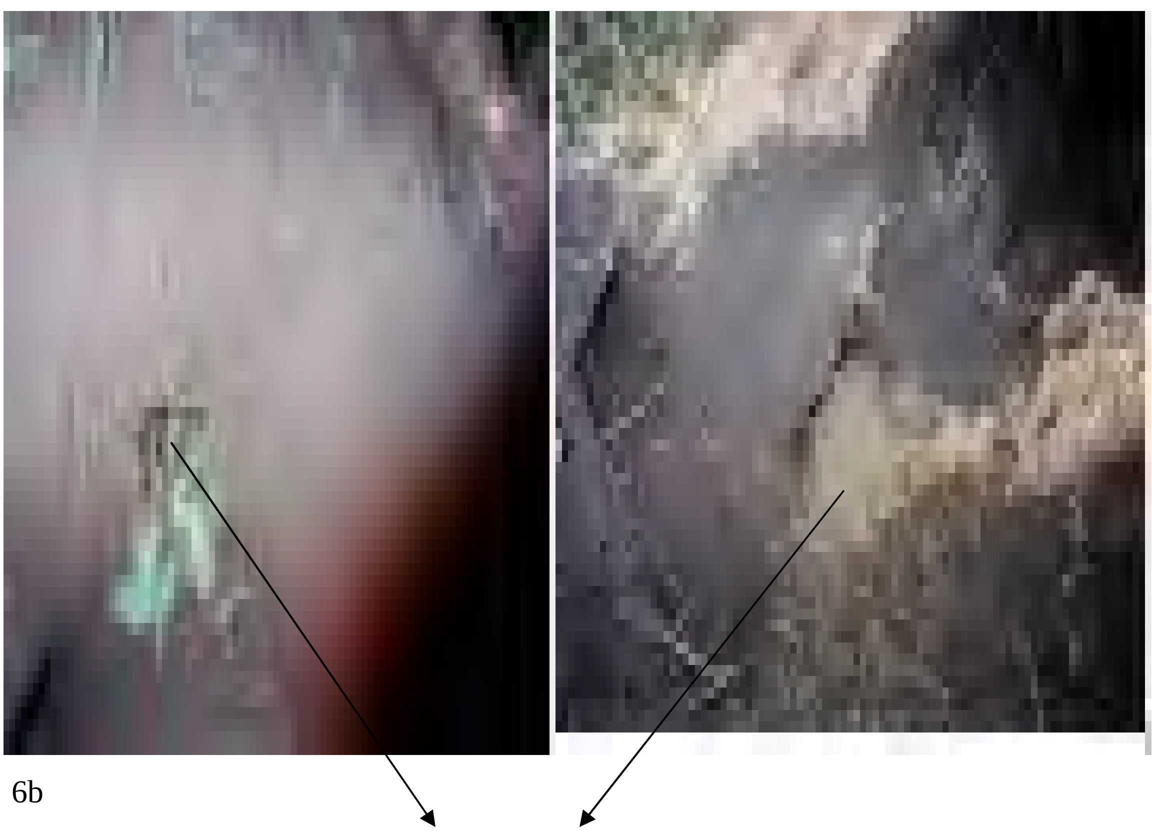
The burrow system of *T. splendens* consisted three components (elements). A single multipurpose nest, bolthole and one or more foraging tunnels. The nest site lies 40 to 60 cm below the ground (Table 8) and its diameter is about 30 cm. Both male and female nests are similar in structure. The nesting chamber consisted of sleeping area with the nesting materials, food storage and sanitary area. The sleeping site is close to entry of nest chamber made of fresh nesting materials (Figs. 6a & b). Food is stored at either side of the nest. The distal region of the nest chamber is a sanitary site packed with old decomposing nest materials and faeces that are rich in compost. It has foul odor. It interlinks one or more tunnels (passages) which makeup the burrow system together. A deep bolthole is often in adjacent to or nearby the nest. The nest contents observed at study sites were grasses (*Cynnodon sp*), potato tubers (*Solium tuberosum*), beans (*Vacia fava*), wheat (*Triticum sativum*) and barley (*Hordeum sativum).*

Table 8. Burrow system measurement length (m) and depth in (cm). - = the animal or bolthole not observed (found).

Study sites	Burrows	Age/Sex	Burrow length in m	Depth and length				
				Foraging tunnel		Bolthole		Nest
				Depth in cm	Length in m	Depth in cm	Length in m	Depth in cm
An-01	A	Adult/M	18.6	15	15.4	125	3.2	60
	B	-	11.4	20	11.3	-	-	40
	C	-	14.45	17	11.25	130	3.2	60
K	E	Adult/M	12.85	15	9.35	150	3.5	50
	F	Adult/F	10.2	21	8.4	120	2.9	60
	G	Adult/M	14.4	17	11.2	140	3.2	45
Ls	J	Adult/M	12.92	18	8.42	160	4.5	50
	K	Adult/F	13.0	21	9.30	190	3.7	60
	L	Adult/F	14.55	20	10.25	140	4.3	55
Sb	W	Adult/M	12.8	21	10.5	170	2.3	60
	X	Adult/F	17.8	18	13.5	130	4.1	50
	Y	Adult/M	15.7	20	12.4	120	3.3	50

6a

Figure 6a. Old nest with stored potatoes and potato scratches



6b

Figure 6b. Nest with fresh and old nesting materials in bean farmland

(Photo Abebe K.)

The bolthole is a blindly ending tunnel. It is associated with nest leading to the deepest part of the burrow system. It starts either directly or fairly nearby the nest chamber. The deepest bolthole with 1.90 m depth was excavated in Lemisuticho burrow systems (Figs. 7, 8, 9k, Table 8), where adult female inhabited. The shallowest bolthole with 1.20 m depth was excavated in Kerekicho site (Table 8, Fig. 9f).

Figure 7. Bolthole
(Photo Abebe K.)

Figure 8. Mole rat within bolthole
(Photo Abebe K.)

Foraging tunnels are cross-sectioned passages with observed diameter and length 7 to 12 cm and 8.4 to 15.4 m, respectively (Table 8, Fig. 9). All the burrow systems excavated were crop fields of Enset, Potato, Cereals and Pulses, and adjacent grasslands. Burrow system of ***T. splendens*** in all four-study sites and its habitats consisted of 15 to 21 cm deep foraging tunnel, a single multipurpose 40 to 60 cm deep nest and 1.2 to 1.9 m deep and 2.3 to 4.3 m long bolthole.

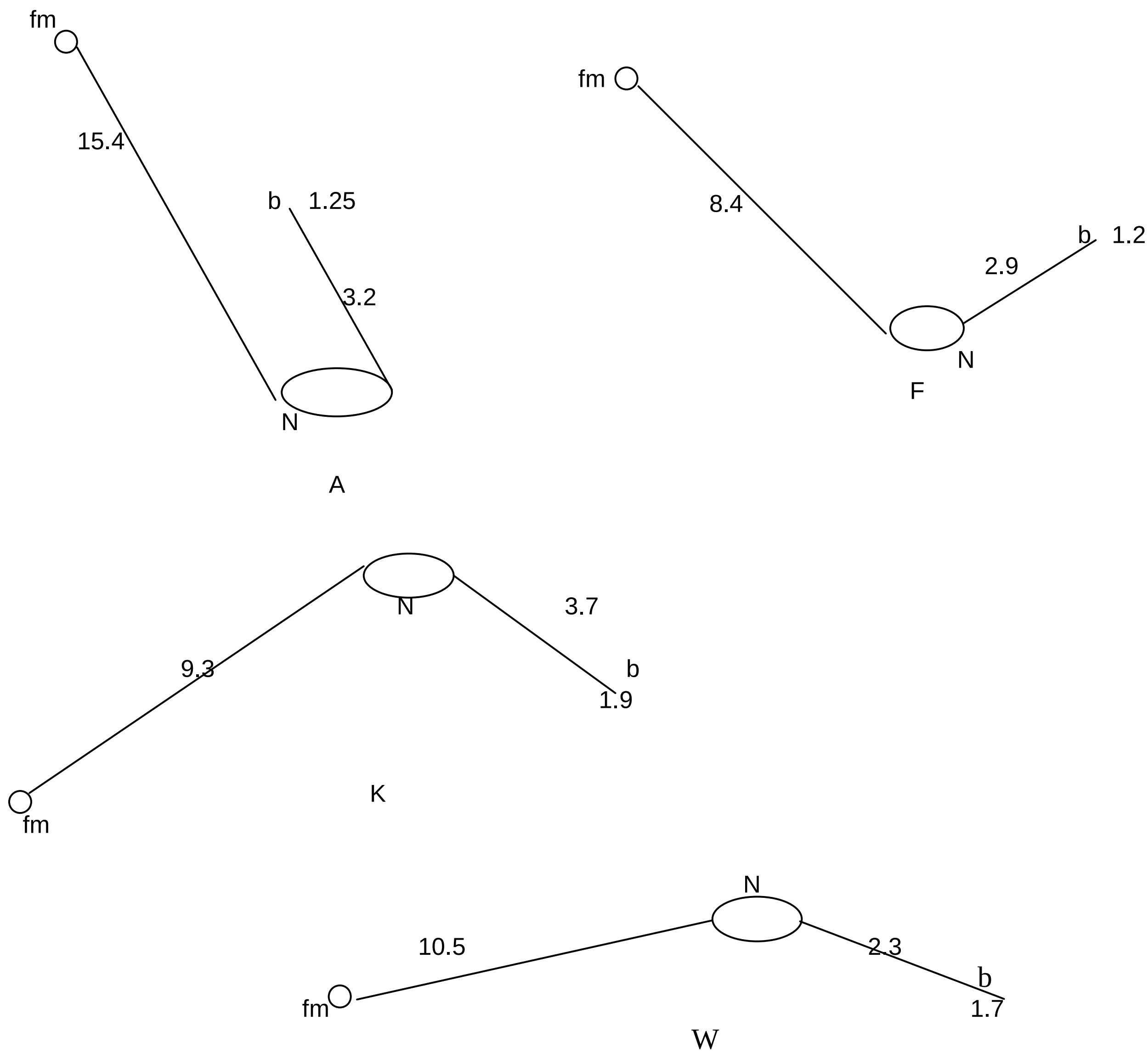


Figure 9. Map of representative burrow systems (A, F, K and W) of each study sites

(fm = fresh mound, N = nest and b = bolthole)

6. 5 Stomach contents analysis

The stomach contents of 28 mole rats were analyzed and directly correlated with the vegetation of the habitat. Grass is predominant, followed by Enset and potatoes (Table 9). Soil particles were also observed in the stomach of the mole rats.

Table 9. Stomach content analysis of mole rats collected from Angacha (An-01), Kerekicho (K), Lemi-suticho (Ls) and Sarara-bokata (Sb) sites. "+" = presence and "–" = absence.

Sites / Sp eaten	Season	An-01	K	Ls	Sb
Enset ventricosum (corm)	Wet	+	+	+	+
	Dry	+	+	+	+
Solanum tuberosum	Wet	+	+	+	+
	Dry	+	+	+	+
Cynadon sp	Wet	+	+	+	+
	Dry	+	+	+	+
Euclaptus	Wet	-	-	-	-
	Dry	-	+	-	-
Erithyrina brucei (Root)	Wet	-	-	+	+
	Dry	-	-	+	+
Soil	Wet	+	+	+	+
	Dry	+	+	+	+
Unidentified	Wet	+	+	+	+
	Dry	+	+	+	+

6. 6. Impacts of mole rats on agriculturally important plants

The observed maximum amount of potato hoarded is 4kg per nest. Since potato yield is more than 100 quintals per ha, the 0.003% loss is insignificant. The estimated damage on cereals, pulses, and grasslands from its soil hill diameter coverage and nesting materials within the nest showed that the loss in grass was high (Fig. 10). The observed minimum and maximum mound diameter with mean and SD was $0.325 \pm 0.05m^2$ and 0.52 ± 0.08 m^2, respectively.

Figure 10 Mole rat mounds on grassland

Severe damage on Enset was observed in "Dega" climatic zone sites Sb and Ls with total damage of 68 and 75, and 75 and 65 during wet and dry seasons, respectively (Table 10). Similarly, the highest percentage loss was observed in Enset plantation in "Dega" climatic zone sites, Ls and Sb (Table 11). Mole rat damage on Enset was severe (Figs. 11 & 12). However, the loss in "Woina-dega" climatic zone sites was low. Two factors ANOVA showed highly significant differences in Enset damage between sites at P < 0.01 (F = 248.82 P= 0.0004). However, there is no significant difference between seasons (Appendix II). Thus, mole rat damage is severe in Dega climatic zone due to its increased density in these sites (Tables 6, 7, 10 & 11).

Table 10. Monthly total count of damaged Enset plants in study sites Angacha-01 (An-01), Kerekicho (K) Lemi-suticho (Ls) and Sarara-bokata (Sb) for wet and dry seasons.

Seasons	Habitats / Months	An-01	K	Ls	Sb
Wet	August	5	4	26	28
	September	3	2	24	21
	October	2	3	25	19
	Total	10	9	75	68
Dry	December	4	3	25	26
	January	2	3	22	24
	February	3	2	18	25
	Total	9	8	65	75

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Table 11. Percentage loss of Enset plants and income reduction due to mole rat impact.

Study sites	Wet season		Dry season		Annual % loss	Annual loss in birr
	Loss in %	Loss in birr	Loss in %	Loss in birr		
Angacha-01 (An-01)	2.25	180	2.0	162	4.25	342
Kerekicho (K)	2.2	162	2.25	144	4.45	306
Lemi-suticho (Ls)	9.73	1358	10.71	1170	20.44	2520
Sarara-bokata (Sb)	9.07	1224	9.73	1014	18.8	2238

Figure 11. Damaged young Enset plants.

(Photo Prof. Afework B.)

Figure 12. Damaged medium aged Enset plant.

(Photo Prof. Afework B.)

6. 7. Results of interviews to determine pest status and control mechanism

Sixty-four randomly selected farmers, 16 farmers in each site were interviewed (Appendix IV) about the behavior of the animals and their impact on agriculturally important crop plants. 78% of them considered the animal as a serious pest on Enset, grass and potatoes. They employed trapping and burrowing to regulate out break of mole rat population (Table 12).

Table 12 Results of interview to determine pest status and controlling mechanisms of mole rats in Angacha-01 (An-01), Kerekicho (K) Lemi-suticho (Ls) and Sarara-bokata (Sb) sites.

Variables		An-01	K	Ls	Sb
Most valued crop	Enset	16	16	16	16
	Potato	-	-	-	-
	Cereals	-	-	-	-
Major pest	Mole rat	8	10	16	16
	Porcupine	8	6	-	-
Pest status	Very important	8	10	16	16
	Important	8	6	-	-
	Least important	-	-	-	-
Season of Severity	Wet	4	3	-	-
	Dry	2	2	-	-
	Both	10	11	16	16
Enset loss in %	25	-	-	8	9
	20	2	1	4	4
	≤ 10	14	15	4	4
Controlling mechanisms	Traps, rodenticides & burrowing	4	3	2	4
	Trapping & burrowing	12	13	14	12

7.2. DISCUSSION

7.1. External body measurements

The common mole rats are highly variable in color even within a narrow range of habitat. Because of this, color variations are not considered in this investigation. Even though, karyotype analysis was not carried out due to time and chemical constraints, external body (morphometric) measurements showed that there were no significant variations in four characters out of five standard external traits, namely TL, HB, T and HF. However, weight has highly significant variation within the study sites. Highest weight was observed for An-01 and the least for Sb. However, An-01 is significantly different from Sb in weight. These morphometric results lie within the features of the species ***T. splendens*** as shown by Afework Bekele (1986), Kingdon (1974), Nowak (1999), Sewnet Mengitu and Afework Bekele (2003) and Yalden (1976). Additional study might be essential to ensure the existence of subspecies and other species within the genus *Tachyoryctes* in the present study area and elsewhere in Ethiopia. Karyotype analysis has prime importance in such investigation as already observed by Basckevich *et al.* (1993), Matthey (1976) and Jotterand-Bellemo (1984).

7.2. Abundance and distribution

In the study area, the distribution of the East African common mole rat, *T. splendens* was discontinuous as revealed by Kingdon (1974, 1997) and Nowak (1999) earlier. The distribution pattern was different and fluctuated seasonally depending upon altitude, vegetation and climatic factors like precipitation as observed by Jarvis (1973), Jarvis and Sale (1971) and Nowak (1999). The present investigation area is very habitable for mole rat distribution. The altitudes, vegetation cover and climatic factors favored the abundance and distribution of the animal in all sites of the district. Since the habitats are highly managed agricultural fields, seasonal cultivation might have affected the density of the mole rat population. Mole rats are known to be very sensitive to habitat disturbances.

The common mole rats were most abundant within the habitats of Serara-bokata (Sb) in both wet and dry seasons. The mole rat density per ha was 15 and 12 during wet and dry seasons, respectively. The least abundance of mole rat was observed for Angacha-01 (An-01) habitats. Jarvis (1973) observed the density of common mole rats per ha as 200 in natural and stable habitats in Chiromo, Kenya. Nevertheless, in the present study, only 15 individuals per ha from Angacha were observed. This might be due to the regular cultivation of the habitats. The crop fields were cropped and cultivated at least twice per annum and they are not stable. The density of mole rat increases when habitat disturbance is limited. This is also observed within all sites of Angacha. The highest mole rat density per plot and per hectare was observed in those farmlands where farmers are disabled to manage their farmlands. The "Dega" climatic zone sites possessed more individuals than "Woina-Dega" climatic zone habitats.

The Highest density for common mole rat was recorded in grassland followed by Enset in each study sites during the wet season. The least infested crop field is sugarcane. Therefore, crop fields (habitats) vary significantly in mole rat density in all localities for both wet and dry seasons (Table 7). Thus, mole rats relatively prefer open grasslands to the other crop fields as seen in the observation of Jarvis and Sale (1971), Kingdon (1974), and Nowak (1999).

There were no significant seasonal variations in density of mole rats within habitats and the different study sites. seasonal population density difference is low within the habitats. Therefore, population density increases, as altitudes, precipitation increases where habitats are stable and food resources available. Stability of habitats affects their foraging vegetation abundance and distribution. This agrees with the statements of Jarvis and Bennett (1991), Jarvis and Sale (1971), Sewnet Mengistu and Afework Bekele (2003) and Shimelis Beyene (1986) for its close relative species, *T. macrocephalus*.

7.3. Common mole rat burrow system and its ecology

The critical issue for common mole rat is finding suitable habitats where they live and reproduce. For many rodents including the common mole rats, subterranean burrows play an important role in interaction with the environment. Burrows of mole rats were used for refuges, foraging and storages and breeding as well as nest sites (Fig. 9) as observed by Carter and Encarnnaca'o (1983), Carter and Rosas (1997) and Jarvis and Sale (1971). Common mole rats prefer porous well-drained soil, open habitats with suitable vegetation for feeding and ventilation. The topography, soil, climatic conditions and the vegetation of the habitats in the present study area favored local distribution of common mole rats as stated by Brown and Hickman (1973), Vleck (1981), Antinuchi and Busch (1992) for subterranean life.

The present study showed that burrow system of ***T. splendens*** consisted of three elements. A single multipurpose nest for breeding, sleeping, storage and sanitation (Figs. 6a,b), bolthole to retreat when alarmed (Figs. 7, 8) and one or more foraging tunnels to survey food sources. The investigation in this study strongly agrees with findings and arguments of Jarvis (1973) and Jarvis and Sale (1971). The nest contents are grasses, cereals and pulses, potato tubers, roots of *Erithyrina brucei* and unidentified plants. Among the invertebrates, unidentified bugs and spiders were common. Although these were common in the nest, the perennial plant, Enset corms were not found in any nests of the entire study sites. This shows that Enset corm is not stored in the nest for adverse environmental conditions. Nevertheless, they extend their foraging tunnels to Enset plots through the strips of grassland.

The investigation in all four-study sites and different habitats within them revealed that the burrow system consisted of 15 to 21 cm deep and 8.4 to 15.4 m long foraging tunnels, a single multipurpose 40 to 60 cm deep nest and 1.2 to 1.9 m deep and 2.3 to 4.5 m long bolthole (Table 8, Fig. 9). This agrees with the findings of Hickman (1979), Jarvis and Sale (1971) and Nevo (1961). Foraging tunnels make up 82.6 % of the excavated burrow system. They are within the percentile range of 80 – 95% as described by Antinuchi and

Busch (1992), Heth (1992), and Jarvis and Sale (1971) for subterranean mammals (Table 8, Fig. 9). However, the total length of the burrow system, 10.2 – 18.6 m is highly reduced. This deviation disagreed from findings of Jarvis and Sale (1971), 18 – 52 m at Chiromo Estate and Mount Kenya in Kenya. The difference in the length can be attributed to the availability of enough resources within a short distance. The deviation signifies that how much the length of burrow system varies with soil type, topography, vegetation and availability of food as well as the number of individual animals per burrow system. In the entire burrow system, a single mole rat was frequently found confirming that it is an exclusively solitary and aggressive mammal. This behavior is observed in captured male and female mole rats at Angacha. They do not even show opposite sex behavioral attraction. The habitats of the study area are fertile agricultural farmlands with strips of grasslands. These are suitable to mole rats providing the necessary food resources. Availability of food resources in agricultural fields within short length (distance) resulted in a decrease in the total length of burrow system as well as foraging tunnel. However, the other influencing factors like altitude, precipitation and temperature would have to remain constant. Nevertheless, the depth and length of bolthole increased contrary to the findings of others. The habitats are periodically cultivated. They are always in disturbance due to the nature of crop field management. Thus, stability of habitats and availability of food resources are important to determine burrow locations and burrow system size, and density of *T. splendens*. The present study indicated that foraging is the critical element of the common mole rat to occupy habitats. This indicated that mole rats co-evolved the system of practicing below ground storage organs of plants like all other subterranean organisms (Vleck, 1979). In the present investigation area, underground food stored plant parts were predominant. This practice might have favored the animal to inhabit successfully throughout the district.

Stomach contents of mole rats in each locality showed that more than 95 % of food sources are underground parts of the vegetation. Among these, grass is in large proportion followed by Enset and potatoes (Table 9). The least proportion is registered for cereals, pulses, and *Erithyrina brucei*. However, among the cereals, sorghum and maize have highest proportions in An-01 and K habitats. The habitats were rich in grasses, Enset corms, potatoes, and garden vegetables like cabbages, sugarcane and fenced trees namely *Pinus* sp and *Erithyrina brucei* (Table 9). The presence of soil in the stomach may lead to conclude that soil microbiota are required to digest its fibrous food sources or might have slipped unintentionally during burrowing. The requirement of soil microbiota to digest fibrous food has been observed in the close relative species, naked mole rat, *Hetrocephalus glaber* by Jarvis and Sharman (2002). This requirement might be a rule for all subterranean animals.

Foraging in *T. splendens* is mostly below ground through the foraging tunnels. The depth of foraging tunnels was regulated by the level of root, stem tubers and corms of the plants that they feed (Table 8). This investigation strongly agrees with the findings of Yalden (1975) for *T. macrocephalus*, Hickman (1979) for *Cryptomys,* and Jarvis and Sale (1971) for the same species. The foraging tunnels are not used only for foraging, but also to air tightly plug in order to maintain humidity and temperature as observed by Hickman (1977) and to protect themselves against predators.

The bolthole serves as escaping tunnel whenever the animal is alarmed. In this study, mole rats were caught within the bolthole in all burrow systems (Figs. 7 & 8). This indicates that bolthole serves as an escaping passage as observed by Jarvis and Sale (1971). However, Hickman (1977) suggested that the bolthole keeps humidity high in the burrow system. Although the physiology and behavior of mole rats were not well studied, boltholes primarily provide refuge against any source of danger. In addition, it might serve to maintain the animal's body temperature and humidity during seasonal fluctuations. Finding and locating bolthole is not an easy task since it is plugged in similar manner as undisturbed soil ground in nature by mole rat.

7. 4. Population structure

In the present study area, the population density of ***T. splendens*** was high in “Dega” climatic zone habitats. However, sex ratio and age structure showed no significant differences between climatic zones even though they were male biased. The population density of the ***T. splendens*** is very low compared to other studies. This might be due to its solitary behavior; distribution in patchy territorial ranges and managed habitats compared to the findings in undisturbed and stable areas. In addition, the population structure of the species revealed that a pattern of reproduction and population growth is low since common mole rats, ***T.*** *splendens* in each sites are male and adult biased. The sex ratio is 2.1:1.0 and age structure 78.58% adult and 21.42% subadults and juveniles were significantly different at $P < 0.05$ and $P < 0.01$, respectively. The population structure in this study varied and does not go in line with the findings of Jarvis (1973) which is 66% adult. However, the dominance of adults compared to other age groups agree with the findings of others. Thus, the population structure revealed that adults are more active and dispersed. Juveniles were not observed in the nest during burrowing even though the locals suggested that it gives birth to one or two pups per litter. This was only observed in one pregnant trapped female. In the uterus, there were four embryos. Since the animal gives birth to 1 or 2 pups per litter, resorption of embryo should be common. There was four teats. However, the number of teats and pups were not correlated since the ratio of teats to pups is 2:1.

7. 5. Impacts of mole rat in agriculturally important plants

In the present study has revealed that the damage on Enset plantation and grassland was high due to the attack of mole rats. However, the yield loss for potato, cereals and pulses was insignificant. Enset is the co-staple food of the inhabitants. Farmers give priority to Enset plantation and cabbage (Table 12). Their food security is entirely dependent on Enset plantation. Loss of Enset means loss of livinghood in the district. This life-supporting plantation is highly exposed to mole rat infestation and the transmitted disease known as Enset bacterial wilt. Damaged Enset plants can be at any of the three stages such as young, medium and matured plants. The young are more susceptible to mole rat damage compared to medium and matured plants (Fig. 11). The maturity of Enset plant requires 5 to 7 years. Each plant costs 15 to 20 birr. Matured Enset plant costs in average about 18 birr per plant. In the present study, highest damage was registered at “Dega” climatic zone and low for “Woina-dega” climatic zone. The percentage loss analyzed for each study site showed that Lemi-suticho scored highest damage followed by Serara-bokata. However, the percentage loss for Angacha-01 and Kerekicho was low. Despite this, the annual loss in percentage for each study sites (An-01, K, Ls. and Sb) is 4.25, 4.45, 20.44 and 18.8, respectively. The mean loss is nearly 12 %. However, the actual percentile loss is 11.985 % at the district level. The intense damage in Ls and Sb has led some farmers to abandon their Enset plantation or shift the plot. The percentage loss when converted to income loss in terms of money valued about 710.15 birr per individual farmer per site. The 12 % loss for perennial plant, Enset plantation is very high. This agrees with the results of interviewed farmers (Table 12). Two factors ANOVA showed significant variations between sites of “Dega” and “Woina-Dega” climatic zones at $P < 0.01$. However, the difference in loss is not significant seasonally. The present study showed that mole rat damage on Enset plantation is within the range of other rodent pests (http://user.Ugent.be\ Rodent pests in Somalia and their control 27/05 06). According to Aplin (2003), cited in Http://user.Ugent.be\ rodent damage loss ranges between 10 to 15%. Nevertheless, in the present investigation, the percentage loss of Enset was deviated from Afework Bekele and Leirs (2003) rodent damage (26.4 %) in maize fields in Ziway, Central Ethiopia. This shows that the impact of rodents varies depending upon the crop type. However, in such densely populated and with reduced farmland size where the population entirely depends on garden sized Enset plantation, the loss is very high. Therefore, common mole rat is the major and economically important pest of Enset plantation in the district. This might be true to other districts harboring 10 million people whose staple or co-staple food is Enset. Mole rats not only act as a pest, but they also served as vector or intermediate host to transmit Enset bacterial wilt (file://E\ Mole Rats 5/8/2006). Enset bacterial wilt might wipe out the whole Enset plantation during the period of high incidence.

Mole rats were common in open grasslands bordering Enset plantations and other crops in the farmland. Farmers retain these grasslands as a forage source for their cattle. However, these served as the main outreach for the rodent pest mole rat to move to crop fields (Fig. 10). Mole rats extend their foraging tunnels to Enset and other agriculturally important crop plant farmlands. Within the grassland, each soil hill (mound) of mole rats covered an area from 0.33 m^2 to 0.52 m^2 (Fig. 10). The mounds that covered grasslands reduce grass yield that supports cattle. It is known that the grass harvested from 2 m^2 feeds at least 4 cows per day. Loss or reduction of grass will result in less food for cattle. In the present study, highly reduced size of farmland, large family size and main dependency of food security on monoculture, Enset was observed. This increases the complexity of life in the region among rodent pest, mole rat and human society. Mole rats are the major pests of Enset, grasses and potatoes. Thus, proper control and sustainable management of mole rats is pre-requisite for food security in the district.

7.6. Control and management of common mole rat

Protection of crop plants from mole rat damage was important for food production and to alleviate food security. In the studied area, human competition for food with the rodent pests is high. To minimize the problem and to increase the output, the framers employ rodenticides, fungicides, and fertilizers. Despite the employment of rodenticides, adverse environmental effects and low success in biological control strongly showed that the biological interactions involved in mole rat management is little known. More attention should be given in using multifaceted approach (IPM) in order to control and manage rodent pests, thereby increase in crop yield as observed by Allen and Bath (1980).

Mechanical methods in the use of local traps to control and reduce mole rat population were observed as an alternative to chemical control. Economic, ecological, sociobiological and environmental consequences are diverse. This was in line with (htm: 21/2/2006 Why study rodent populations). Thus, knowledge of biological interaction is important to secure food, manage the rodent pest and maintain ecological balance. Since mole rats prefer open grasslands adjacent to Enset and other farmlands, avoidance of growing grasses in nearby crop fields is indispensable to minimize shelter areas. Proper periodical cultivation as well as introduction of indigenous predators (owls, cat and eagles) helps to reduce and regulate mole rat population.

8. CONCLUSION AND RECOMMENDATIONS

The present study on mole rat ecology and its impact in agricultural fields at Angecha revealed different ecological parameters. External body measurement in this study showed that there was no significant variation from the population of other localities of Ethiopia. Nevertheless, there were variations in abundance, distribution and density of mole rats between sites and habitats (crop fields). The cause of these variations could be altitude, climatic factors, availability of food resources and regular agricultural field cultivation and management. The density of mole rat in this study highly deviated from findings of others. Thus, abundance, density and availability of food resource as well as stability of habitats are directly correlated.

The present study indicated that the length of burrow system is highly reduced in crop fields and adjacent grasslands to minimize expenditure of energy. However, the length and depth of the bolthole increased to protect itself from danger. The depth of bolthole was more in “Dega” climatic zone than “Woina-dega” climatic zone. Thus, the animal uses the bolthole for both protections against alarm and to maintain body temperature. Despite this, an exclusively solitary behavior of the animal and the burrow component nest, foraging tunnels and bolthole were similar to findings of others.

In the present study, mole rat impact on agricultural fields, especially on Enset and adjacent grasslands is high, but minor for other crops. Annual Enset plant damage is about 12 % for the whole district. However, annual loss in “Dega” climatic zone sites Ls and Sb is about 20 % while in “Woina-dega” climatic zone sites the loss was about 4 %. Thus, mole rats are major rodent pests of Enset though its impact was minor in potatoes, cereals and pulses. Considering living status of farmers, even little damage will have a big economic impact. Priority should be given by the concerned institutions to minimize the damage.

The following recommendations were suggested based on the findings of the present study.

- ♣ Further study using DNA; karyotype number and karyotype morphology may help to ensure presence of subspecies or other species within the genus, *Tachyoryctes* in the district, and throughout the distribution range of the country as well as East Africa.
- ♣ Behavioral and physiological study of the animal in captive conditions might be helpful to understand the subterranean ecology, population structure and solitary nature of the mole rat.

- ♣ The present study confirmed that mole rats are major rodent pests on Enset by using adjacent grasslands though its effect was minor on other crop plants. They are also intermediate hosts in the transmission of Enset bacterial wilt. Hence, in order to reduce damage on Enset and other crops: -
    - ➢ Avoid or shift adjacent grasslands from crop fields to long distances.
    - ➢ Use of local traps and burrowing in groups, at least in village level is important.
    - ➢ Introduce indigenous predators to reduce the population size.

- ♣ Carry out more work to understand the biological interaction of the animal in order to conserve and maintain the ecological balance.

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Appendix I. Two factors for mole rat distribution and density in study sites An-01, K, Ls
and Sb

Anova: Two-Factor Without Replication

SUMMARY	***Count***	***Sum***	***Average***	***Variance***
Al	2	26	13	2
K	2	30	15	2
L	2	29	14.5	4.5
S	2	35	17.5	0.5
Wet	4	64	16	2.666667
Dry	4	56	14	4.666667

ANOVA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Sites	21	3	7	21	0.016226	9.276628
Seasons	8	1	8	24	0.016277	10.12796
Error	1	3	0.333333			
Total	30	7				

Anova: Two-Factor Without Replication

SUMMARY	***Count***	***Sum***	***Average***	***Variance***
Inset	2	36	18	8
Potato	2	24	12	2
Cereals	2	24	12	0
Grassland	2	36	18	2
Wet	4	64	16	16.66667
Dry	4	56	14	8.666667

ANOVA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Habitats	72	3	24	18	0.020172	9.276628
seasons	8	1	8	6	0.091721	10.12796
Error	4	3	1.333333			
Total	84	7				

Appendix II. Two factors ANNOVA for damage of Enset in Sites An-01, K, Ls and Sb

Anova: Two-Factor Without Replication

SUMMARY	***Count***	***Sum***	***Average***	***Variance***
Al	2	4.25	2.125	0.03125
K	2	4.45	2.225	0.00125
L	2	20.44	10.22	0.4802
S	2	18.8	9.4	0.2178
Wet	4	23.25	5.8125	17.23323
Dry	4	24.69	6.1725	22.01349

ANOVA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Site	117.2689	3	39.08962	248.82	0.000429	9.276628
Season	0.2592	1	0.2592	1.649905	0.289174	10.12796
Error	0.4713	3	0.1571			
Total	117.9994	7				

Appendix III. Two tailed t-test for body measurements of mole rats and weight at Angecha study sites.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	An_01 - K	10.00000	36.74235	16.43168	-35.62165	55.62165	.609	4	.576
Pair 2	An_01 - Ls	7.50000	28.72281	14.36141	-38.20441	53.20441	.522	3	.638
Pair 3	An_01 - Sb	54.00000	19.49359	8.71780	29.79551	78.20449	6.194	4	.003
Pair 4	K - Ls	-10.00000	11.54701	5.77350	-28.37386	8.37386	-1.732	3	.182
Pair 5	K - Sb	45.00000	28.10694	11.47461	15.50358	74.49642	3.922	5	.011
Pair 6	Ls - Sb	50.00000	23.09401	11.54701	13.25228	86.74772	4.330	3	.023

Appendix IV

Farmers questionnaires

I. Background 1.Age of respondent .... 2. Residence ....

a. District ....b Kebele .... c. Village .... d. Climatic Zone ....

3. Education of respondents

a. None formal ....b. Primary ....c. Secondary ....d. Above Secondary......

4. Family size .... Male .... Female ....

II. Economic activities (make “X” mark in the box).

1.a. Farming .... b. Trading ....c. Both .... d. Others ....

2. How many hectares of land do you own?

<0.5 ha .... 1 ha .... 1.5 ha .... 2.0 ha .... >2.0 ha ....

3. Cultivated farmland size by crop in hectares

Enset ...... Potatoes .... Others vegetables .... Maize ...... Cereals & Pulses ....

4. Grazing grasslands ....

5. Crop types valued most: a. .... b. .... c. .... d. .... e. ....

III. Crop pests

1.Which crop pest is considered to be economically important? Grade it as:

a. Very important b. Important c. Least important

Pest type	Crop type attacked	Grading
Insects		
Rodents		
Others		

2. Rodent pest of the village:

Mole rat .... Rats .... Porcupines .... Others ....

3. Which of the above rodent pests severely attack the crop plants? .... If mole rats mention the extent of the damage. High .... Medium .... Least ....

4. What part of the crop is most likely attacked? ....

5. The season of the highest mole rat attacks

Dry .... Wet .... Both dry & wet ....

IV. Replanting mole rat attacked fields

1. Do you replanted mole rat attacked fields? Yes .... No ....

2. Which crop fields were replanted? ....

3. What proportion was replanted? ....

4. How much of each crop types is damaged by mole rats? ....

Enset .... Potatoes .... Cereals & pulses .... Grasslands ....

5. Yield loss in: a, Percentage .... b. Terms of money .... Impact due loss ....

V. Method used to control and manage mole rat damage

1. Trapping ....2 Rodenticides .... 3 Others if any ....

4. Which of the above methods were more effective? ....