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Abundance, composition and habitat association of rodents in Wonji Sugarcane Area, Ethiopia

By

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ABSTRACT

A study on the ecology of rodents was carried out in Wonji Sugarcane Plantation from August 2005 to March 2006. Three trapping grids were randomly selected in the sugarcane plantation based on the growth stage of the cane as- immature sugarcane plant (ISP), young sugarcane plant (YSP), and old sugarcane plant (OSP). An additional grid was selected from bushland area outside the sugarcane plantation. A total of 629 captures were made in 2940 trap nights. Out of these, 557 individuals represented eight species of rodents: *Mastomys natalensis*, *Arvicanthis dembeensis*, *Arvicanthis niloticus*, *Stenocephalemys albipes*, *Pelomys harringtoni*, *Mus mahomet*, *Mus musculus*, and *Rattus rattus*. The remaining 72 individuals represented two insectivore species; *Crocidura flavescence* and *Crocidura fumosa*. Abundance of species varied in different growth stages of the sugarcane plantation and bushland area. There was seasonal difference in the abundance of the rodents. However, species composition was the same in all the three growth stages of the sugarcane plants and in bushland area. Variation in trap success with different growth stages of the of sugarcane plantations was significant. All age groups were represented in the population of most species. Breeding was seasonal for most of the species. The pest status of rodents in the sugarcane plantation was assessed. Analysis of the stomach contents of snap trapped rodents from the plantations showed sugarcane fibers that confirm the pest status of rodents in the sugarcane plantation while monocot plants were dominant in rodents captured from bushland area. Population estimation using minimum number alive (MNA) showed decline in each trapping session.

1. INTRODUCTION AND LITRATURE REVIEW

1.1 INTRODUCTION

Ethiopia is one of the most physically and biologically diverse countries in the world (Leykun Abune, 2000). There occur wide variety of habitats ranging from 110 meters below sea level at Kobar Sink in the Afar depression, to a peak of 4620 meters above sea level at Ras Dejen in the Siemen Mountains (Shibiru Tedla, 1995). The country is known for its animal diversity, with 861 species of birds and 277 species of mammals, of which 16 and 31 are endemic, respectively (Hillman, 1993).

It is estimated that 5000 species of mammals exist all over the world. Among them, more than 2000 are rodents. Rodents comprising 40% of the entire mammal species (Meehan, 1984). Among the 84 species of rodents recorded in Ethiopia, 21% are endemic (Yalden *et al.*, 1996). This shows the diversity of rodents in the country, as a consequence of diverse geographical and altitudinal features.

Rodents have influenced history and human endeavor more than any other groups of mammals. They occur in every habitat, from the high Arctic Tundra, where they live and breed under the snow, to the hottest and driest of deserts (Kingdon, 1997). The seasonal distribution and quantity of rainfall is considered as the major climatic variable in determining population dynamics of rodents in East Africa (Delany and Monro, 1985).

Due to their adaptability to wide habitat ranges, rodents often occur in close association with man. This association is not always in tune with the interest of man because rodents consume huge quantities of stored food, and spread fatal diseases (Macdonald, 1984; Leirs *et al.*, 1993).

Most rodent species are known for their troublesome nature to man. They are noxious pests of agriculture, which damage over 30% of the produced food, globally (Fidler, 1988).

Despite their diversity and pest status, studies on rodent pest control measures are meager. Limited work has been carried out on Ethiopian rodents (Afework Bekele, 1996a,b; Afework Bekele, *et al.*, 1993; Afework Bekele, *et al.*, 2003; Afework Bekele and Leirs, 1997; Afework Bekele and Corti, 1997; Lavrenchenko, *et al.*, 1998). Taxonomic collections of rodents in crop fields in Ethiopia, Kenya, Tanzania, and Zambia have been carried out and those that frequent and damage crops in agricultural areas have been identified (Gregory *et al.*, 1999). Afework Bekele and Liers (1997) have revealed that the rodent fauna in grassland habitats and maize fields in central Ethiopia consisted of the same species, but in different relative proportions.

The rodent fauna of Ethiopia consists of 84 species forming more than 25 per cent of the total mammalian fauna of Ethiopia (Yalden and Largen, 1992). Among the rodent species, 15 are endemic, which contribute for 50 percent of the endemic mammalian fauna of Ethiopia (Hillman, 1993). In Ethiopia, *Arvicanthis dembeenisis* and *Mastomys erythroleucus* are the major pests of agriculture (Afework Bekele and Leirs, 1997). It has been estimated that rodents damage 20-26% of the cereal crops in Ethiopia (Afework Bekele *et al.*, 2003).

Man has tried all possible means to minimize the damage caused by rodents. Different types of traps, poisons, barriers, repellants, and predators have been tried. The most commonly used control measure for rodent pests is rodenticides (Stenseth *et al.*, 2001). Killing rodents by trapping, hunting, flooding and by fumigation have been tried traditionally in many places, but rarely achieved great effects on the population (Greaves, 1989). Fertility control has been a theoretical possibility for a long time, but with poor practical results. Recent work on immunocontraception of house mice in laboratory and in enclosed field populations has been promising and revived interest in fertility control of rodents (Parshad, 1999). In spite of all these, rodents have continued to have adverse effects on crops (Leirs, 1994). Even with the advancement of techniques and better understanding of the biology of rodents, the fight still continues.

The problems of rodents are mostly the same in both developing and developed countries. The major difference is that these problems are far more serious, widespread, and difficult to solve in the developing countries. Thus, it is a question of degree than of kind. But this does not mean, however, that knowledge and techniques available in the developed countries are easily applicable in developing countries. Such a view ignores the profound technical, cultural, and political differences not only between the two groups of nations, but also among the developing countries themselves. Moreover, people in developing countries die from starvation because of shortage of food. To make things worse, rodents avail themselves to take their share. At present, the biological method of pest control is gaining popularity as part of integrated pest management. The success of the method depends on the knowledge of ecology of rodents (Tilaye Wube, 1999). It is towards this end that the present study tries to make a contribution.

In Wonji sugarcane area, there are wide ranges of mammalian pests such as, rodents, hippopotamus, warthogs, monkeys, and porcupines (although not seen frequently). In addition, rodents largely use the sugarcane plant as their source of food resulting in the deterioration of the sugarcane plant thereby reducing yield per unit area, increase cost of production and reduce human efficiencies (Tate and Metaferia, 2004). The aim of the present study is to identify and assess the damage caused by mammalian pests in Wonji sugarcane plantation with especial emphasis on rodents.

1.2 LITRATURE REVIEW

1.2.1 Rodents as pest

Rodents are major agricultural pests, globally. They damage and destroy 30% of the crops in both pre-harvest and post-harvest conditions (Singleton, 2001). Fitzgibbon (1997) reported that high immigration rates from adjacent habitats and increased population recruitment owing to food resources lead them to rapid population growth in agricultural fields. Thus, such large populations cause a considerable damage to a wide variety of crops, worldwide.

Rodent outbreaks over large areas have been reported from many localities in Africa. The most common rodents in sub-Saharan African countries are *Mastomys* spp. that occur all over the continent in natural grasslands, cultivated areas and in human habitats. The population explosion occurs at regular intervals. Leirs *et al.*, (1996) has revealed 50% of crop losses during such outbreaks in Kenya. In Ethiopia, although comprehensive studies on the effect of rodent damage to agricultural crops are lacking, Goodyear (1976) and Afework *et al.* (2003) have estimated that rodents destroy 20-26% of cereal crops.

It is known that only a few of the rodents are agricultural pests. There are about 2000 species of rodents, but only a limited number of them cause problems in agriculture (Paul and Robertson, 1989). In Africa, for example, out of the 406 species of rodents, only 77 have been reported to cause damage to agriculture. In Australia, only 7 out of 67; in Europe only 16 out of 61; in India only 18 out of 128 and in Indonesia, only 25 out of 164 species are clearly identified as pests (Table 1). In addition, Afework Bekele and Leirs (1997) have reported that 11 out of 84 species of rodents in Ethiopia were identified as major and minor agricultural pests.

Table 1. Number of rodent species in various geographical regions that are significant pests of agriculture.

Continent/ Country	No. of rodent species present	No. of rodent pests	No. of significant pest species in cropping systems	Conservation status	
				No. of species at risk	Little known
Africa	406	77	12-28	60	11
Austraila	67	7	4	14	1
Europe	61	16	5	4	-
India	128	18	12	21	1
Indonesia	164	25	13	11	28

Source: Fidler, 1988.

In agricultural areas, rodent populations fluctuate from season to season based on various growth stages of the crops. For instance, in cereal crops in the African savanna regions, most damage occurs during the sensitive young seedling stage and just before harvest (Fidler, 1994). Rodent damage may even necessitate late replanting, resulting in lower yields. Although efficient techniques exist to kill rodents, none of the traditional methods has been able to control populations over the long term (Singleton *et al.*, 1999). Methods with immediate effect may be more effective in order to protect the crop during sensitive stages, but only if applied before damage is made (Myllymaki, 1987; Workneh Gebresilassie *et al.*, 2004).

1.2.2 Damage on sugarcane plant

Sugarcane is a *Saccharum* species of grass cultivated in tropical and subtropical countries throughout the world. It may grow to a height of 3 to 6 meters and is about 2 to 5 centimeters thick. Several varieties are commercially farmed which can differ in stem color and height. In some varieties, the leaves fall off before harvesting (Pervez and Ali, 2001). In tropical areas, sugarcane will grow throughout the year and can be harvested between January and August. When the stems are cut into pieces with a number of buds on each piece, they are called 'setts', which can be used for propagating the crop (Dubey and Kawasthi, 1991). Further, stems developed from the buds, which grow into stalks or canes are also ready for harvesting from 10 to 24 months. After first harvest, which can be for the production of 'setts' or for processing at the factory, the underground buds on the stool develop to give a second, third or even more crops in a similar or slightly shorter growth period, which are known as ratoon crops (Khan and Smythe, 1981).

Careless use of pesticides, fertilizers, and poor irrigation management in sugarcane areas have resulted in reduced wildlife biodiversity, polluted rivers and seas, eroded fertile soils, polluted air and damaged coral reefs (Fluk *et al.*, 1980). According to Tobin and Sugihara (1992), sugarcane production is becoming more sustainable. For instance, integrated crop management techniques and green harvesting are more common in many countries. Although the environmental record of the sugarcane industry has been poor, steps are being taken to rectify the problems (Smith and Buckle, 1994).

Rodents are major pests of sugarcane. They usually gnaw lower internodes of sugarcane and cause direct damage at the sugar formation stage of the crop. Besides their direct damage, they also expose the cane increasing the risk of infection by bacteria and fungi (Meyer, 1994). Rao (2003) reported that in the 1999-2000 harvest season, rodents in Australian cane fields destroyed approximately 825,000 tones of sugarcane valued at US$ 50 million. In Hawaiian sugarcane plantations, they caused severe losses that have been estimated as 4.5 million dollars annually (Leung, 1998). In Ethiopia, although the occurrence of rodent damage on sugarcane is known, there are no studies that provide quantitative data, so far.

Rodents colonize cane fields because they provide relatively an undisturbed habitat for burrowing, feeding and breeding. The sugarcane fields also provide them protective cover from avian predators for most part of the year (Parshad, 1999). Although they get all these advantages, they cannot subsist on sugarcane alone. As rodents need additional protein, they supplement it from sources such as earthworm, spiders and other insects. Moreover, Hoque *et al.* (1988) revealed that in Hawaiian sugarcane fields, sugarcane comprises about 70% of the rodent diet by volume, while in surrounding non-crop vegetation, it comprises from 20 to 50%. Most rodents living in cane fields either die or migrate to surrounding areas during harvest, and therefore, their populations do not rebuild until the second half of the crop cycle (Gratz, 1996). In addition, during much of the first year, the sugarcane stalks stand erect, the crop canopy is open, and most fields have little ground cover.

Therefore, most rodents prefer to forage in adjacent areas of the young sugarcane fields.

All stages of sugarcane are victims of rodent pests, although the degree varies. For instance, in ratoon cane, they gnaw the stems and apical meristems of young plants. But as the cane grows, they attack the mature stalks, resulting in reduced sugar content and harvestable tonnage (Wilson and Whisson, 1993). Movements and home ranges in sugarcane fields also vary depending on the age of the crop, population density, and other factors. In general, males travel farther than females, but the home ranges of both sexes decrease as the sugarcane matures (Tobin *et al.*, 1990). Usually, rodent damage in sugarcane fields is identified by open holes at lower internodes and small chips on the ground where they have fed. Mwanjabe *et al.* (2002) explained that rodent depredation can be distinguished easily from that of feral pigs (*Sus scrofa*). Pigs chew on the entire stalk, leaving it with a shredded appearance.

1.2.2.1 Immature sugarcane plants

The field of very young sugarcane plant, which is about 1 to 8 months old, is usually considered as immature sugarcane. Although there are numerous rodents in the adjoining non-sugarcane areas, there are few in the immature sugarcane fields. This is due to the fact that, it provides very little cover and food, as the cane has not yet lodged or a mat of stalks and dead leaves have not developed on the ground (Whisson, 1996). Khokhar and Razvi (1998) stated that there is no rodent damage to sugarcane for the first four months of age. As a result, control measures are not recommended at this stage. According to Rajab *et al.* (2003), rodent damage may commence when the cane is nearing 7-8 months. During this period, rodent control should be initiated in the surrounding non-crop areas to reduce the population before they move in.

1.2.2.2 Young sugarcane plants

Sugarcane plants of about 8-15 months are considered as young. Unlike the immature sugarcane, more ground cover is present at this age. Stalks are lodged that produce mat and leaves on the ground. Many rodents begin living in the field, digging burrows and building nests as adequate food sources and nesting sites are available in the field (Clements, 1980). Moreover, they reduce their daily movements and seldom forage into the surrounding non-crop areas. At this stage, rodents attack the internodes of the growing stalks of the cane. The injuries may either kill the stalk or severely reduce sugar production as microorganisms enter the wounds and cause souring (Blackburn, 1984). Caughley *et al.* (1998) concluded that the losses caused by microorganisms are more severe than the amount of cane the rodents actually consume.

1.2.2.3 Mature sugarcane plants

Sugarcane plants of about 15 months old until harvested at 24 months are considered as mature. The cane at this stage provides dense cover and enough food for relatively high populations of rodents. During this period, rodent damage is extensive. Fauconnier (1993) reported that about 5% of the stalks are attacked each month in Hawaii. At harvest, 20 to 40% of the stalks are damaged. Clements (1980) suggested that the cane at this stage needs maximum protection and follow up by the growers to rescue the plants from severe rodent damage.

1.2.3 Rodent pest management

Among many causes of poverty, rodents have a major share. Especially in those countries that live far below the poverty line, rodent pests are partially responsible for food insecurity. For instance, in Tanzania, the average annual yield loss of maize by rodents is 5-15%. This corresponds to more than 400,000 tons of maize, which is equivalent to an amount that could feed 2.3 million people for a whole year (FAO, 2002). Therefore, rodent pest management should be given priority for a sustainable global food security.

For centuries, rodents have been a problem for humans. They have found human civilization to be ideal environments for sources of food, shelter, and for transportation to new territories, and even to continents. This has been responsible for rodent pest outbreaks in urban, agricultural, and other environments throughout the world (Gratz, 1997). Historically, vertebrate pest problems have not received as much attention as other agricultural pests. Public health problems and the economic aspects of rodent infestations have, in many instances, overshadowed the pest status associated with rodents (Krebs, 1999). However, due to the diversity between rodent pest and the agroecosystems where they occur, a number of management strategies have been designed in the past. Most of them have been successful under specific conditions and this has encouraged people to try to apply them elsewhere in very different ecosystems. However, none of them is a panacea. The people who designed those methods are well aware of this fact. But policy makers do not always appreciate the details that make a strategy useful in one area but not necessarily elsewhere (Makundi *et al.*, 1999). In the past, human has used various rodent pest management strategies to reduce the problems that rodents cause. Some of the methods used were burning vegetation around, trapping and poisoning as well.

The primary aim of rodent pest management is to reduce rodent population at or below economically and culturally acceptable levels rather than to eradicate them (Adler *et al.*, 1996). The principles of efficient rodent control have been established over the last fifty years with the advances in knowledge of the biology of the pest, the continual development of improved rodenticide formulation, and methods of application and increasing appreciation of the management procedure (Kotler, 1984). Moreover, as Rao (1992) suggested, the benefits of non-chemical methods of rodent control are increasingly recognized. However, lethal chemical agents are presently the main stay of all practical rodent control programs both in the urban and agricultural environments and this situation is expected to remain for long. The reasons for this are the great strides towards the increased safety of rodenticides with the introduction of anticoagulants.

1.2.3.1 Biological control

Biological control is the means of reducing pests with predators. It is an effective method for rodent control (Chambers, *et al.*, 1999). But as Chambers *et al.* (1997) revealed, the use of animals such as cats, dogs, and snakes are ineffective for the economic control of field rodents. Instead, the other form of biological control (killing) through the introduction of diseases is a relatively alternative solution, although there is a general concern that these diseases may be spread to humans and domestic animals unless maximum precautions are practiced. Moreover, there are also other biological control methods, involving altering rodent fertility, use of immunosterilants delivered by a virus vector. However, the success and side-effects on humans, domestic animals and other non-target and beneficial organisms of this interesting approach is yet to be fully evaluated and determined (Leirs, 1999).

According to Singleton *et al.* (1999), biological control method is founded on two ecological principles: 1) organisms can be used to control another and 2) some control organisms have a limited host range. Host range generally refers to the set of species on which a control organism can feed and develop. The safe and effective use of biological control requires assessment of the ability of the control organisms to harm non-target organisms, to survive, to reproduce, to disperse, and to evolve. Ideally, biological control represents a pest control technology that is effective, environmentally safe and self-sustaining with minimal need for repeated interventions. However, some of the characteristics that make biological control organisms effective in controlling pests also make them potentially dangerous invaders (Rajab *et al.*, 2003).

In biological control, host specificity tests typically measure the potential of the control organism to complete its life cycle on the target organism and also on the non-target organisms that it consumes (Smith and Buckle, 1994). Although such host specificity tests are necessary to estimate the probability and severity of target and non-target effects, at present they are far from sufficient. Because a control organism may harm a non-target one in several ways such as direct trophic interaction, direct interference competition and indirect interactions that may arise when the control organism and the non-target organisms interact via intermediate species. Therefore, there should be a critical thinking before applying this control method to rescue the non-target species from total extermination.

1.2.3.2 Chemical control

Currently, chemical control is the primary method for managing rodents (Buckle, 1994). But as Fiedler (1994) reported, in developed countries the use of chemicals raises a number of concerns such as the risk to non-target species, the humaneness of its action, high usage patterns, conflict with marketing and low efficacy of action when high quality food is available. In developing countries, these issues also apply with the additional concerns of affordability, quality control of products and correct usage patterns.

1.2.3.2.1 Rodenticides and Types

Rodenticides are chemicals that are used to kill rodents. The requirements by which to judge the potential of a compound to act as an effective rodenticide should depend on its efficacy and safety (Buckle, 1994). The efficacy of a rodenticide is determined by several factors. Among these, toxicity to target rodents is one of the prerequisites of a rodenticide. Furthermore, rodenticides can be more useful if they are potent to a wide range of target species; and are equally effective against all individuals regardless of sex, age, and strain (Ferguson, 1980). On the other hand, specificity to rodents is one of the safety requirements of a rodenticide that is highly desirable.

Rodents are the prey base of predators in many ecosystems. Due to this fact, they may expose their predators to rodenticides if the predators are preyed upon either poisoned rodents or scavenge their dead bodies. Therefore, compounds that are rapidly broken down in the bodies of rodents and that are not secondarily toxic are desirable (Savarie, 1991). In addition, as explained by DeLai (1997), the need to use rodenticides near man and domestic animals because of the pests' commensal nature, leads to accidental exposure of non-target animals to rodenticides. Thus, the availability of a specific antidote is of great importance. A slow mode of action is also highly beneficial on these occasions so that sufficient time is available to recognize the symptoms of poisoning and administer the antidote, in case human beings and domestic animals are accidentally exposed to such a situation.

There are different types of rodenticides. The majority these rodenticides are administered as poisoned baits, although some compounds are available in forms such as liquid, contact dust, and poisonous gas (Smith *et al.*, 2002). They are classified into two major categories: acute (fast acting) rodenticides and anticoagulants (relatively slow acting). But more recently, the development of several rodenticides that are in some respects intermediate has resulted in the third group, sub-acute rodenticides.

Acute rodenticides are fast in action. The onset of toxicity is rapid after an effective dose has been ingested. Generally, symptoms appear in less than 24 hours and with some compounds in minutes itself (Meehan, 1984). However, rodents may repel to eat the poisoned bait, eventually. Therefore, these rodenticides may not be as effective as anticoagulants. Moreover, due to their effects on non-target animals, there are limitations in their usage in most countries. Hence, acute rodenticides can be applied only by professionals. Often, their use is further restricted to premises, which can be locked or to locations such as warehouses, sewers, and ships inaccessible to the public (Palazoglu *et al.*, 1998). Zinc Phosphide, Sodium Fluoroacetate, Fluoroacetamide, Alphachloralose, Thallium Sulphate, and Red Squill are some commonly used acute rodenticides.

The subacute rodenticides have more or less similar characteristics with acute rodenticides except in some aspects. When these rodenticides are applied, rodents may take lethal dose of these compounds during the first 24 hours, but repeated feeding may occur and death is normally delayed for several days (Eason *et al.*, 1999). Calciferol, Bromethalin and Flupropadine compounds are sub acute rodenticides.

Anticoagulants are rodenticides, which have slow mode of action as compared to the acute ones. They reduce the clotting abilities of the blood and cause death as a result of hemorrhage. This anticoagulant effect is brought about indirectly by the rodenticide interfering with the function of vitamin K in the liver, which is responsible for the synthesis of blood clotting factors, 'prothrombin complex'. The effect of these rodenticides generally takes 4-10 days. This delay prevents rodents from associating the symptoms of toxicosis with the anticoagulant that has caused it and, therefore, bait shyness is unknown (Mount *et al.*, 1986). There are two groups of anticoagulants: first generation anticoagulants, and second generation anticoagulants. The former include compounds developed as rodenticides prior to 1965 (Greaves, 1989; Buckle, 1994). The latter was developed for the control of commensal rodents in areas where they had become resistant to the first generation anticoagulants.

1.2.3.3 Ecologically based rodent management

Ecologically based management of rodents aims at combining basic and applied research on rodents by focusing on their population ecology and developing management actions directed at the agro-ecosystem level. It is a concept that was developed in developing countries since the late 1990s (Krebs, 1999). According to Leirs (1999), this concept is appealing because it promotes actions that facilitate sustainable agriculture and has minimum environmental impacts. However, to apply this management technique effectively, it requires a good understanding of the basic ecology of individual rodent species. This in turn, is dependent on access to field methodology that enables to understand the population dynamics and field ecology of rodents.

Chambers *et al.* (1999) explained that this method is based on the sound knowledge of farming systems and natural factors, such as the availability of food and shelter that contribute to the limitation of rodent pest populations. For these reasons, modification of habitats to minimize the availability of food and shelter for rodents by controlling the growth of grasses and synchronizing planting and harvesting are important.

In the process of developing effective ecologically based rodent management, learning cycle that involves phases of observation, formulation and testing of hypothesis with each round of activities leading to better understanding is important. But, despite the nature of the learning process, it is useful to distinguish the three distinct phases in any investigation of rodent problems. These phases are defining the problem clearly, detailed ecological and historical studies and designing and testing management options (Leung, 1998).

1.3 OBJECTIVES OF THE PRESENT STUDY

General objective

- The general objective of the present study is to carry out a survey of rodent fauna and their ecology in Wonji sugarcane farm and nearby bushland areas.

Specific objectives

The specific objectives of the study are the following:

- To identify the type of rodent species in the area.
- To study the composition and abundance of rodents at different growth stages of the sugarcane plant.
- To evaluate the pest status of rodents in the sugarcane plantations.
- To study habitat association of different rodents species.
- To suggest ecologically sound rodent control and management program for sugarcane plantations.

2. THE STUDY AREA AND METHODS

2.1 The Study area

The present investigation was conducted at Wonji-Shoa Sugarcane Plantation, which is located at about 100 km southeast of Addis Ababa. It is situated between $8^{O}31'$ N and $39^{O}12'$ E with an average elevation of 1540 m asl (Fig. 1). Furrow irrigation system is used to water a total land of 7022.24 ha, out of which 1118.67 ha is owned by seven local cooperative farmer associations. With close collaboration and technical advice from the experts of the factory, they grow and supply sugarcane to the factory. Availability of sufficient water is essential for growing sugarcane in Wonji area. In view of this, an efficient system was developed through the years that comprise irrigation canals with a total length of 300 km, drainage canals measuring 200 km, and numerous small artificial lakes. All these water canals are dependant on Awash River (Wonji/Shoa Sugar Factory Working Manual, 2004).

Among the many varieties of sugarcane in the world, ten major cane varieties are grown in this plantation. These are B52-298, CO-421, M165/38, NCO-334, N-14, DB414/66, Mex54/245, B58-230, B59-212, and B41-227. Of these, B52-298 is widely grown and forms the dominant variety in the area. The cane plant flourishes in a wide variety of soils, ranging from very heavy clay soils to light clay soils. Soils in the area are locally classified as A_1, A_2, BA_{14}, and C_1. The plantation has flat topography and sugarcane is cultivated as perennial monocrop.

The way to establish a cane field is by planting setts. Seeds are used only for breeding new varieties. But growth of the cane also begins with tillering followed by crop growth, crop maturity and harvest. When crop yield becomes too low, new setts are planted. Therefore, the crop cycle of the cane can be looked at two stages: the first from the original sett planting to new sett planting and the second from sett planting or the previous harvest to the following harvest. The first or complete crop cycle lasts from 3 to 10 years (or longer if the crop is badly managed). The second is called the harvest or annual cycle and usually lasts from10 to 24 months.

The climate of Wonji area is tropical with seasonal wet and dry seasons. Short rains (March to May) merge into the main rainy season from mid-June to mid-September (Fig. 2). The annual relative humidity ranges between 34.5- 63% (Fig. 3). The mean annual rainfall is 825 mm. The mean monthly temperature minima range between 6.9^{O}C and 14.7^{O}C, and that of maxima between 23.1^{O}C and 30.0^{O}C (Fig. 4). The minimum temperature was 6.9^{O}C, registered in November and the maximum temperature 30.0^{O}C, registered in May. The hottest month of the year is usually May and the coldest is November.

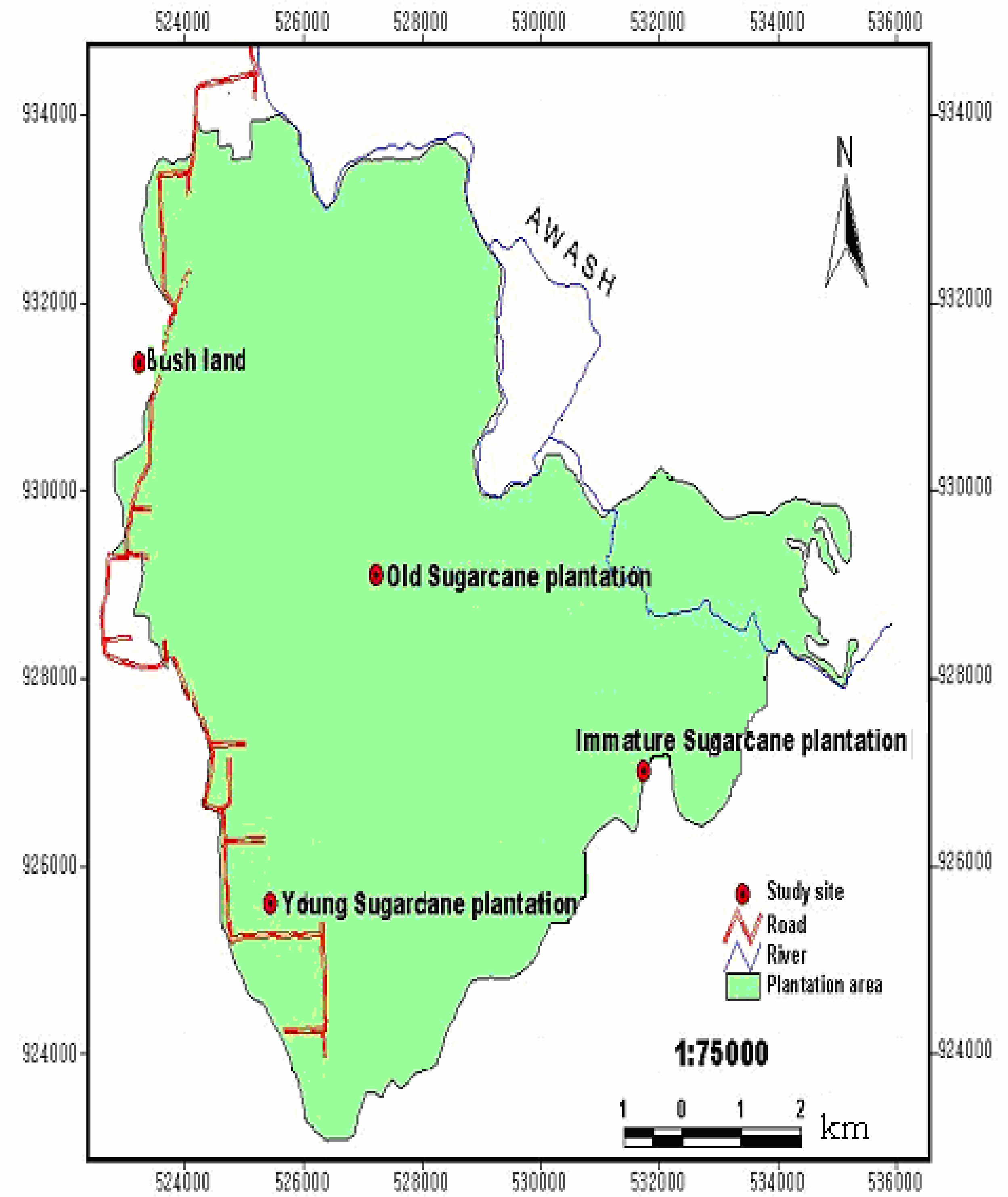

Figure 1. Map of Wonji Sugarcane Plantation and study sites

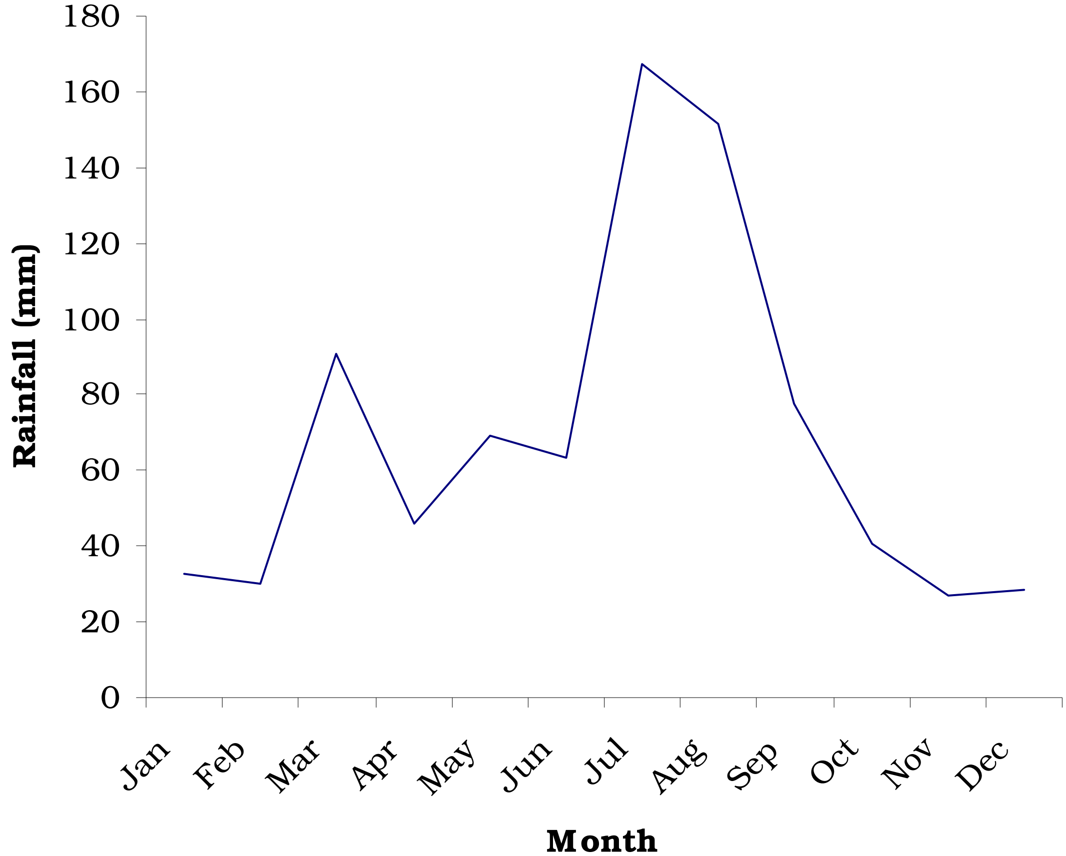

Figure 2. Monthly average rainfall in Wonji area (2000-2005).

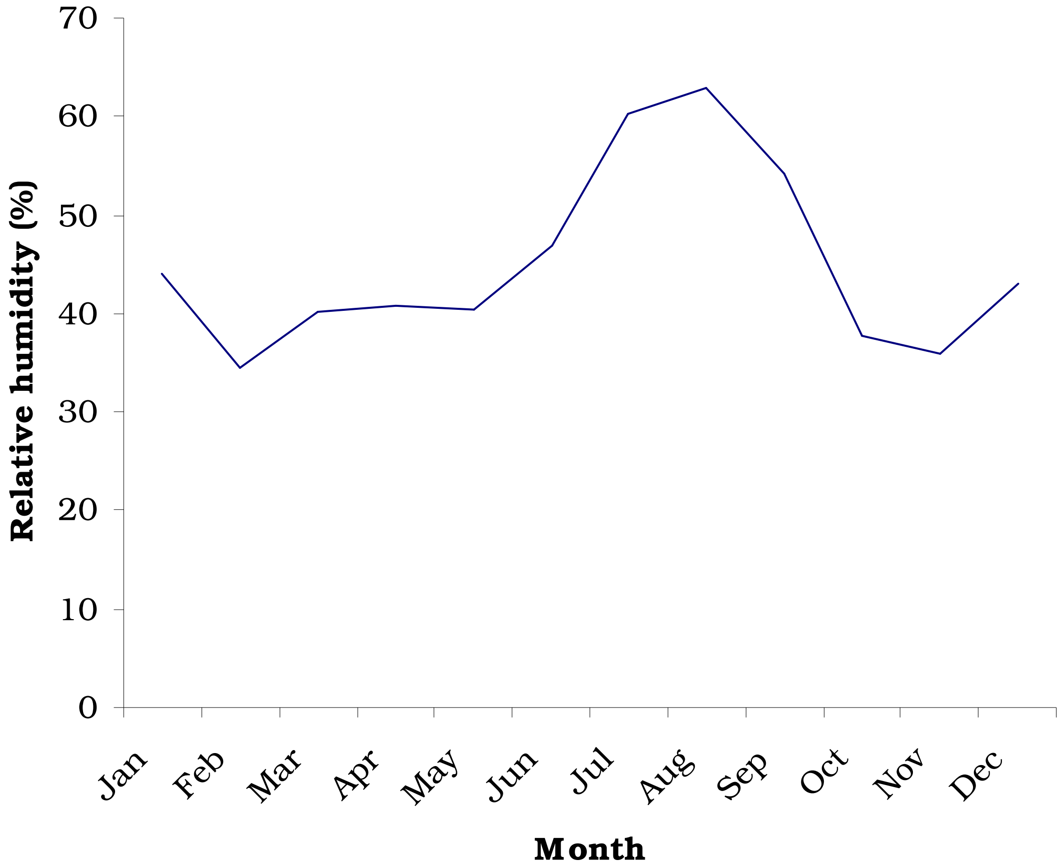

Figure 3. Monthly average relative humidity in Wonji area (2000-2005).

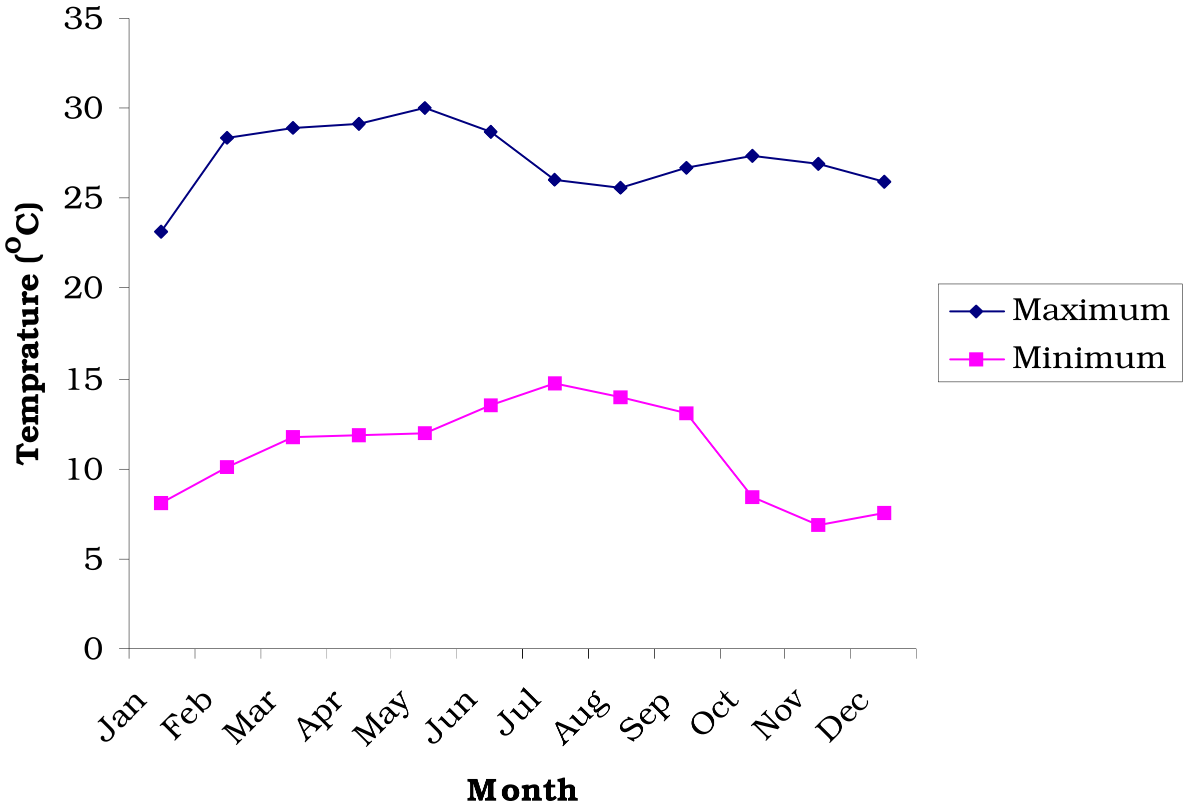

Figure 4. Monthly average maximum and minimum temperature in Wonji area (2000-2005).

2.2 Methods

2.2.1 Data collection

Data on the composition, abundance and habitat association of rodents in Wonji sugarcane plantation were collected for both wet and dry seasons using standard trapping techniques. This was conducted twice in the wet season (August and September) and three in the dry season (November, January and March) from August 2005 to March 2006. Further, data on the occurrence of other pest mammals such as hippopotamus, warthogs, monkeys, and porcupines were also collected during these periods.

2.2.2 Sampling design

Based on a topographic map of Wonji Shoa Sugarcane Plantation (1:75000), four sample areas were selected randomly. Among these, three were in the plantation, and one was a bushland 200 m away from the adjacent sugarcane plantation, near to a rock hill (Plate 2b). Sample areas in the plantation considered the age of the cane. In this view, the 1st sample area contained immature (very young) sugarcane plantation that was a plant cane (PC) and had B52-298 cane variety (Plate 1a). Similarly, the second sample area contained a PC that was old aged and had NCO-334 cane variety (Plate 2a). The third sample area contained a 2nd ratoon sugarcane which was young aged and had B52-298 cane variety (Plate 1b).

2.2.3 Grid design

Three grids, each of 70x70 m (4900 m^2) in the plantation and one grid of 120x40 m (4800m^2) in bushland were established to gather information on live-trapped specimens. In the plantation, the grids consisted of 7 parallel lines, 10 m apart with a trapping station every 10 m, resulting in 49 trapping stations. Trapping stations were marked with white scotch tape, approximately 1 m above the traps. The extent of damage by rodents and insectivores at different growth stages of the cane was recorded. Each grid was further subdivided into 49 cells of 100 m^2 area. Out of the 49 cells in a grid, 12 cells (24.5% of the total) were randomly selected and individual stalks that were damaged by rodents in these cells were counted in both seasons to calculate the extent of damage by rodents. The total stalk count per hectare was known from the factory's record.

2.2.4 Trapping

Sherman live traps were used to trap rodents in the main plantation and nearby bushland area. Moreover, snap traps that were placed at 20 m interval, 200 m away from Sherman live traps were used. Each trap was baited with peanut butter and was checked twice a day, early morning hours (7:00-8:00 a.m.) and late afternoon hours (5:00-6:00 p.m.). The trapped specimens were removed from the trap and kept in polyethylene bag. For each individual trapped, grid and trap-station number, toe-clipping code, body mass, and sexual condition were recorded. In addition to the above, body measurements were taken from the snap trapped animals. Sexual conditions in males were detected by the color and position of testicles (scrotal or abdominal) following Ghobrial and Hodieb (1982). Among females, pregnant ones were identified by their enlarged nipples, large swollen abdomen and body weight. Age structure (adult, subadult and young) was also recorded based on their weight and pledge color (Afework Bekele, 1996a).

Dissection of all snap-trapped animals was carried out for stomach content analysis. The stomach contents from the dissected animals were removed and preserved in 70% alcohol. The contents were put on a glass slide and observed under a light microscope to identify the type as well as proportion of the diet following the techniques of Leirs (1994).

2.2.5 Data analysis

The relative abundance of rodents in the plantation and nearby bushland area was assessed as the percentage of trap success between seasons and different growth stages of the cane plants. Trap success was calculated by using the number of caught individuals and trapping nights. Further, the population of rodents in each trapping sessions and grids was estimated by minimum number alive (MNA) estimation method. This is a method of enumerating only the new individual at each trapping session (Krebs, 1998). SPSS (14.0) computer program was used to analyze the data. Moreover, Shannon-Weaver Index (H') and Simpson's Similarity Index (SI) were used to compute rodent species diversity in different growth stages and the similarity of these stages in respect to the presence of rodent species, respectively.

3. RESULTS

3.1 Species abundance

From five trapping sessions during the study, a total of 629 captures were made in 2940 trap nights. Among these, 557 individuals (88.6%) represented 8 species of rodents and 72 individuals (11.4%) represented two species of insectivores. Among these rodents, 357 were recorded as new captures. Among the insectivores, 49 individuals were recorded as new captures. The trapped rodent species were: *Mastomys natalensis*, *Arvicanthis dembeensis*, *Stenocephalemys albipes*, *Pelomys harringtoni*, *Mus mahomet*, *Mus musculus*, *Arvicanthis niloticus*, and *Rattus rattus*. The insectivores were *Crocidura flavescence* and *Crocidura fumosa* (Table 2). In addition, porcupine, the largest rodent in the area and other large mammals such as warthogs, hippopotamus, and monkeys were observed in the sugarcane plantation.

3.1.1 Abundance of rodents and insectivores in different growth stages of the cane

M. natalensis contributed the largest number of individuals constituting 27.33% of the total catch. It was trapped from all the three growth stages of the cane in large numbers than any other species. In immature sugarcane plant (ISP), young sugarcane plant (YSP) and Old sugarcane plant (OSP), it constituted 24.2%, 32.8%, and 31.4% of the total catch, respectively. *Arvicanthis* contributed the second largest number of individuals constituting 20.4% of the total catch. *A. dembeensis* and *A. niloticus* were trapped from all growth stages of the cane.

Table 2. Species abundance of rodents and insectivores in Wonji Sugarcane Plantation (Figures in parentheses are recaptures).

Family	Species	Total capture	Abundance, %
Muridae	**Mastomys natalensis**	181(70)	27.33
	Arvicanthis dembeensis	96(31)	16.00
	Stenocephalemys	94(35)	14.53
	albipes	63(28)	8.62
	Pelomys harringtoni	40(8)	7.90
	Mus mahomet	26(4)	5.42
	Mus musculus	32(14)	4.40
	Arvicanthis niloticus	25(10)	3.70
Soricidae	**Rattus rattus**	39(13)	6.40
	Crocidura flavescence	33(10)	5.70
	Crocidura fumosa		
Total	10	629 (223)	100

The third largest number of individuals constituted 14.53% of the total catch was *S. albipes*. These were more in number in YSP that constituted 37.3% of their total catch. The *Mus* species, *M. mahomet* and *M. musculus* comprised 13.3% of the total catch. They were relatively more in number in OSP. *P. harringtoni* and *R. rattus* comprised 8.62% and 3.70% of the total catch, respectively. These were relatively more in number in YSP. *C. flavescence* and *C. fumosa* in YSP contained 32.7% of the shrew species catch. The overall difference of species abundance between ISP, YSP and OSP was significant ($\chi^2 = 30.9$, df= 2, $p < 0.001$) (Table 3).

In bushland area (BLA), *Arvicanthis* (*A. dembeensis*, and *A. niloticus*) contributed the highest number of individuals constituting 30.6% of the total catch in the area. *M. natalensis* and *P. harringtoni* were also recorded as 19.8% and 18.2% of the total catch, respectively. Moreover, *Mus* species (*M. musculus* and *M. mahomet*), *S. albipes* and *R. rattus* were recorded 8.3%, 8.3%, and 4.9% of the total catch, respectively. Shrew species (*C. flavescence* and *C. fumosa*) constituted 9.9% of the total catch in this area.

3.1.2 Abundance of rodents and insectivores at different seasons

Some of the rodent species showed differences in their abundance during wet and dry seasons. *M. natalensis*, *S. albipes*, *M. mahomet* and *M. musculus* were abundant during the wet season in the plantations. *A. dembeensis*, *A. niloticus*, *P. harringtoni* and *R. rattus* were abundant during the dry season (Fig. 5). The overall difference in abundance of rodent and insectivore species between the two seasons was significant ($\chi^2 = 9.5$, df= 1, $p < 0.001$).

Table 3. Abundance of rodent and insectivore species at different growth stages of the sugarcane plantations and in bushland area (ISP= Immature sugarcane plant, YSP= Young sugarcane plant, OSP= Old sugarcane plant, BLA= Bushland area).

Species	Growth Stages of Sugarcane			BLA	Total
	ISP	YSP	OSP		
	Number of caught				
M. natalensis	15	45	27	24	111
A. dembeensis	8	23	5	29	65
A. niloticus	2	6	2	8	18
S. albipes	9	22	18	10	59
P. harringtoni	3	6	4	22	35
M. mahomet	7	8	13	4	32
M. musculus	5	5	6	6	22
R. rattus	2	6	1	6	15
C. flavescence	6	8	5	7	26
C. fumosa	5	8	5	5	23
Total abundance (%)	15.3	33.7	21.2	29.8	100 (406)

The seasonal abundance of *M. natalensis* (χ^2= 16.7, df= 1, $p< 0.001$), *M. mahomet* (χ^2= 15.1, df= 1, $p< 0.001$), *M. musculus* (χ^2= 8.9, df= 1, $p< 0.01$), *S. albipes* (χ^2= 4.9, df= 1, $p< 0.05$) and *A. dembeensis* (χ^2= 5.5, df= 1, $p< 0.05$) was significant. However, *A. niloticus*, *P. harringtoni*, *R. rattus*, *C. flavescence* and *C. fumosa*, showed no significant difference between seasons ($p> 0.05$).

3.2 Species composition of rodents and insectivores at different seasons and growth stages of the cane

Species composition between the two seasons was similar (10:10). Nevertheless, the composition of species between seasons in each growth stages of the cane had some difference. YSP had the highest species richness during the wet season, and ISP had the lowest species richness in the same season. In the dry season, plantations of all growth stages had the same species richness. Some species, which were trapped during the wet season, were not captured during the dry season and vice versa. For instance, in ISP, *Arvicanthis* (*A. dembeensis* and *A. niloticus*) and *R. rattus* were captured only during the dry season. But *P. harringtoni* was trapped only during the wet season. In YSP, *M. mahomet* was not captured during the dry season. In OSP, *A. niloticus* and *R. rattus* were not captured during the wet season and *P. harringtoni* was only trapped during the wet season (Table 4, Fig. 6).

On the other hand, in bushland area (BLA), there was a relatively high species richness during the wet season. However, except for *M. mahomet*, all other species were also captured during the dry season.

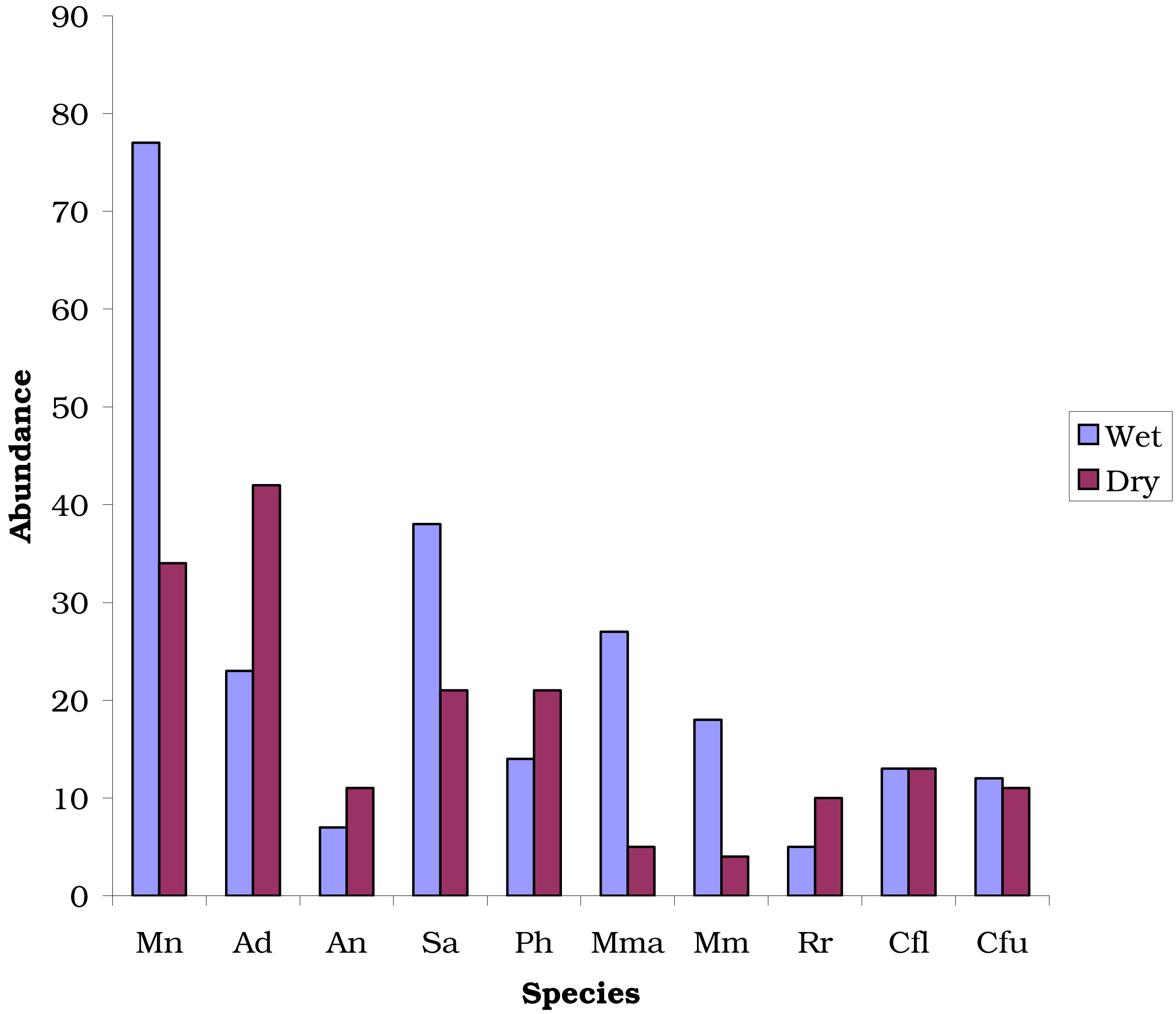

Figure 5. Abundance of different species of rodents and insectivores in Wonji Sugarcane Plantations during wet and dry seasons regardless of habitat type (*Mn=M. natalensis, Ad= A. dembeensis, Sa = S. albipes, Ph = P. harringtoni, Mma = M. mahomet, Mm = M. musculus, An = A. niloticus, Rr = R. rattus, Cfl = C. flavescence, Cfu = C. fumosa).*

Simpson's similarity index (SI) was used to assess the similarity within the sugarcane plantations and between all including BLA. Regardless of seasons, SI was 1 but in considering the two seasons (wet and dry), it was, 0.80 and 0.88, respectively. Moreover, the Shannon-Weaver-Index (H') result for the species diversity was 2.104, 1.983, 1.921, and 2.02 for ISP, YSP, OSP, and BLA, respectively.

Table 4. Seasonal species composition in different growth stages of the sugarcane and in bushland area (Dash indicates absence of capture).

Species	Growth Stages of Sugarcane							
	ISP		YSP		OSP		Bushland	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
M. natalensis	4	11	30	15	18	9	17	7
A. dembeensis	–	8	9	14	1	4	11	18
A. niloticus	–	2	4	2	–	2	3	5
S. albipes	3	6	13	9	6	12	6	4
P. harringtoni	3	–	3	3	4	–	4	18
M. mahomet	3	4	8	–	8	5	4	–
M. musculus	2	3	4	1	4	2	5	1
R. rattus	–	2	2	4	–	1	3	3
C. flavescence	2	4	3	5	3	2	4	3
C. fumosa	3	2	3	5	2	3	4	1
Species total	7	9	10	9	8	9	10	9

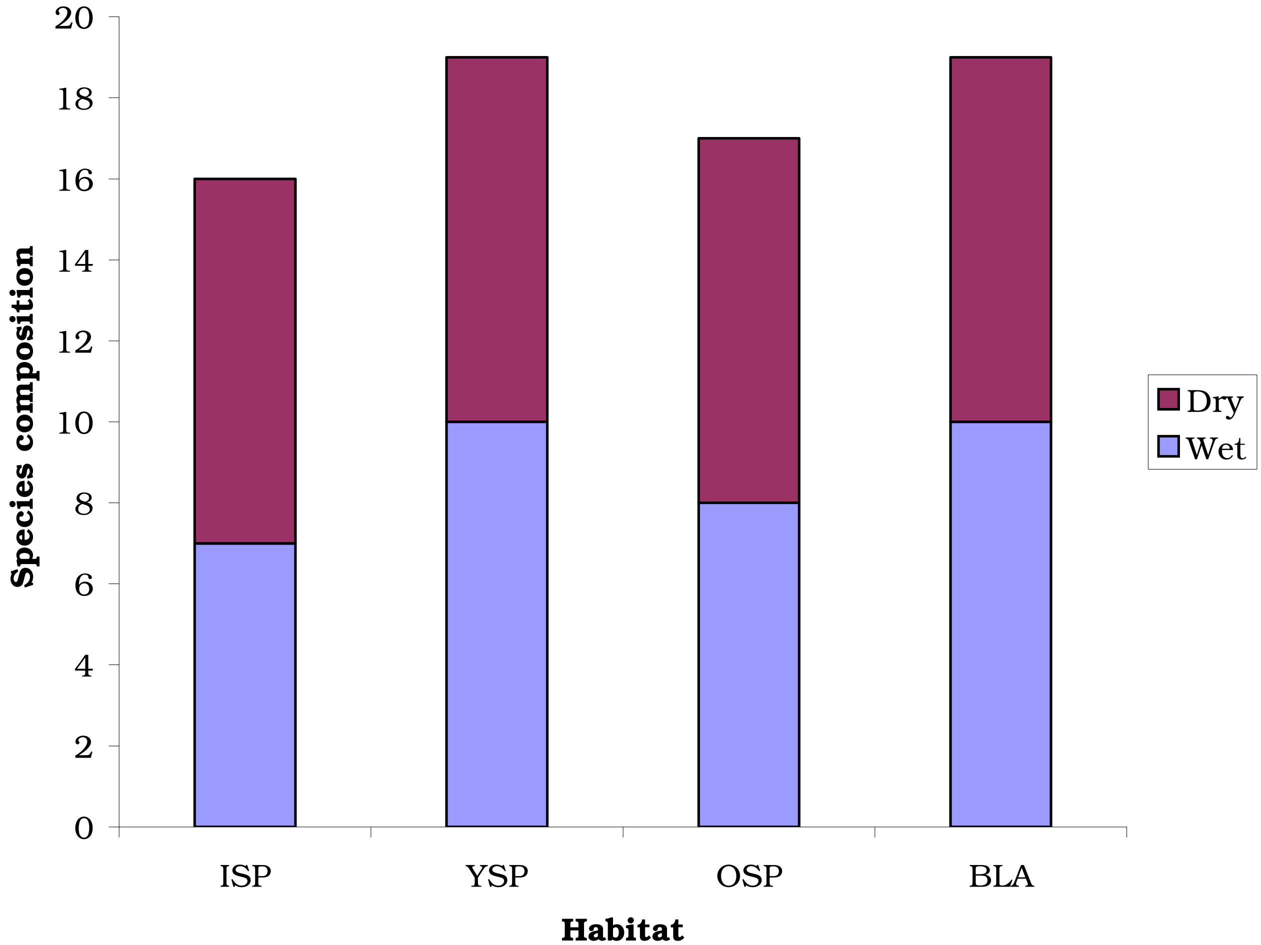

Figure 6. Species composition in different growth stages of the sugarcane plant and bushland area in both seasons (ISP= Immature Sugarcane Plantation, YSP= Young Sugarcane Plantation, OSP= Old Sugarcane Plantation, BLA= Bushland Area).

3.3 Trap success at different seasons and growth stages of the cane

Trap success in all growth stages of the cane was computed. The trap success from the highest to the lowest was: YSP (18.6%), OSP (11.7%), and ISP (8.4%)(Fig. 7). Variation in trap success between ISP, YSP, and OSP was significant ($\chi^2 = 4.2$, df= 2, $p < 0.05$). Trap success for the wet season was 19.9% and for dry season, it was 9.7% across all habitat type. During the wet season, YSP and OSP showed high trap success of 26.8% and 15.6%, respectively. In this season, trap success among the different growth stages of the cane was significant ($\chi^2 = 12.3$, df= 2, $p < 0.01$). Similarly, during dry season, the highest trap success was recorded in YSP (13.1%). However, variation of trap success in ISP, YSP, and OSP during this season was not significant ($p > 0.05$). Furthermore, trap success within two seasons was also computed for each growth stage of the cane (Table 5). YSP showed variation ($\chi^2 = 4.7$, df= 1, $p < 0.05$) whereas, for other growth stages, it was not significant ($p > 0.05$).

In bushland area (BLA), the overall trap success was 16.4%. There was high trap success during the wet season. However, variation in trap success between seasons was not significant ($p > 0.05$).

Table 5. Trap success of rodents and insectivores at different seasons and growth stages of the cane and in bushland area.

	Season	Trapping nights	Captured	Trap success
ISP	Wet	294	20	6.8%
	Dry	441	42	9.5%
YSP	Wet	294	79	26.8%
	Dry	441	58	13.1%
OSP	Wet	294	46	15.6%
	Dry	441	40	9.1%
BLA	Wet	294	61	20.7%
	Dry	441	60	13.6%

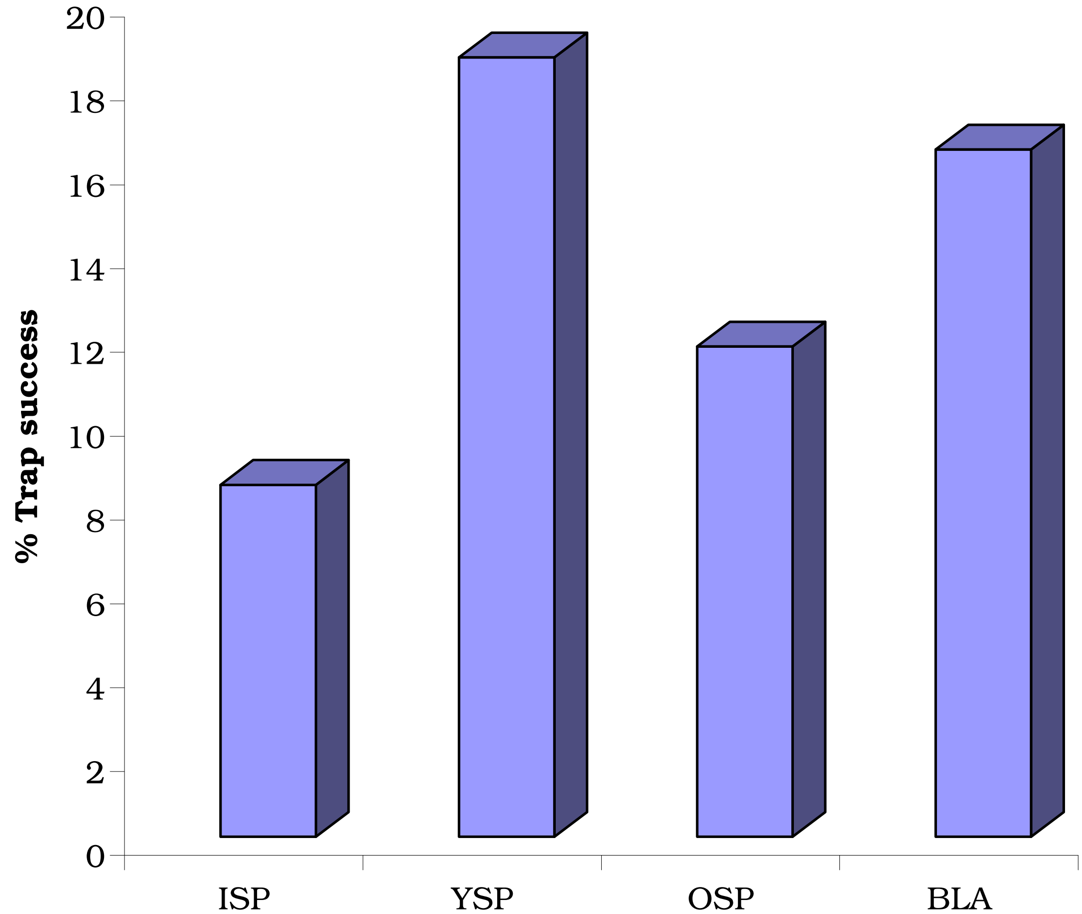

Figure 7. Overall trap success in the three growth stages of the cane and bushland area.

3.4 Age structure and Sex ratio

Young, subadult and adult individuals constituted 39.4%, 12.9% and 47.7%, respectively. During the wet season, young animals accounted for 28.6%, whereas subadult and adult animals accounted for 12.0% and 59.4% of the total capture, respectively. During the dry season, more young individuals (44.0%) were trapped than adult (42.0%) and subadult (14.0%) individuals. The number of subadult individuals in both seasons was less. In both seasons, no subadult individuals were trapped for *A. niloticus, P. harringtoin, M. Mahomet, R. rattus and C. flavescence.*

The difference in the sex ratio was not significant (male: female:: 49.0:51.0). This was also true for sex ratio between seasons (49.4:50.6 for dry and 48.7:51.3 for wet season, respectively). However, the sex ratio in *R. rattus* (70:30), *C. flavescence* (38:62) and *M. musculus* (31:69) was significant. For most of the other species, it was more or less the same, though the number of females was a bit more than males.

3.5 Reproductive condition

More pregnant females were caught during the wet season than during the dry season ($\chi^2 = 12.5$, df= 1, $p < 0.001$). During the wet season, among the trapped females, 77.7% of *M. natalensis*, 71.4% of *C. flavescence*, 60.0% of *A. dembeensis* and 50.0% of *S. albipes* were pregnant. However, during the dry season, the number of pregnant females was less in most species. Although adult females of *A. dembeensis and C. flavescence* were caught, no pregnant females were recorded during the dry season. The number of embryos observed in the snap trapped females ranged between 3-9 and 2-5 during wet and dry seasons, respectively (Table 6).

Table 6. Pregnant females and number of embryos recorded during the wet and dry seasons.

Species	Season	No. of adult females	No. of pregnant	No. of embryos
M. natalensis	Wet	18	14	6-9
	Dry	8	2	4-5
A. dembeensis	Wet	10	6	5-7
	Dry	12	_	_
S. albipes	Wet	14	7	4-6
	Dry	6	4	2-5
P. harringtoni	Wet	5	2	3
	Dry	8	3	3-5
R. rattus	Wet	3	1	6
	Dry	4	2	5
C. flavescence	Wet	7	5	4-7
	Dry	4	_	_

3.6 Diet analysis

A total of 40 stomachs of 5 species of rodents and 1 species of insectivore from snap-trap surveys of both wet and dry seasons were analyzed for food contents. Stomachs of *M. natalensis* and *C. flavescence* were taken from YSP, whereas of *S. albipes* and *M. mahomet* were from OSP and ISP, respectively. The stomach of A. *dembeensis* and *P. harringtoni* was obtained from the bushland area. Sugarcane fibers were predominant in the diet of those captured from sugarcane plantations. The diet of *A. dembeensis* and *P. harringtoin* was more of grass. In the stomachs of these species, monocot seeds were observed unlike those captured from the sugarcane plantations. The dominant food item in the stomachs of these species was grass. Some food items that were not categorized were grouped under unrecognized materials (Table 7).

Table 7. Mean percentage of the diet of snap trapped rodents and insectivores

Species	Season	No. of individuals	Identified food items (%)				
			A	B	C	D	E
M. natalensis	Wet	3	67.4	16.3	6.6	-	9.7
	Dry	4	62.7	20.1	5.2	-	12.0
A. dembeensis	Wet	4	-	66.8	14.2	19.0	-
	Dry	3	-	58.3	11.6	18.0	12.1
S. albipes	Wet	3	58.8	17.4	6.9	-	16.9
	Dry	2	52.3	20.8	5.5	-	21.4
P. harringtoni	Wet	2	-	34.3	8.7	27.2	29.8
	Dry	4	-	40.2	9.3	39.0	11.5
M. mahomet	Wet	5	54.2	22.7	10.1	-	13
	Dry	3	48.3	18.3	12.4	-	21
C. flavescens	Wet	4	13.3	16.4	22.6	-	47.7
	Dry	3	8.2	13.8	24.8	-	53.2

A= Sugarcane fibers

B= Grass

C= Animal matter

D= Monocot seed

E= Unrecognized material

3.7 Pest Status

The damaged stalks in all growth stages of the cane were recorded in both seasons. During the wet season, no damaged stalks were observed in ISP, whereas 3332 and 1813 damaged stalks were recorded in YSP and OSP, respectively. This accounts 4.7% of the total stalk for YSP and 3.8% of the total stalk for OSP in the grid. During the dry season, damaged stalks were observed in all growth stages at varying extent. During this season, the highest stalk count was recorded for YSP followed by OSP and ISP. The extent of damage during this season was 2.0% for ISP, 3.14% for YSP and 3.08% for OSP of the total stalk count in the respective grids (Table 8).

Table 8. The damaged stalk counts of sugarcane plants at three growth stages of the cane during wet and dry season.

Growth stages of the cane	Grid area (m^2)	Total stalk count/grid		Stalk count/100 m^2		Average damaged stalk count/100 m^2		Damaged stalk no./ grid	
		Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
ISP	4900	64549	56045	1317	1144	-	23	-	1127
YSP	4900	70560	60860	1440	1242	68	39	3332	1911
OSP	4900	47029	38102	960	778	37	24	1813	1176

3.8 Population estimation

Population estimates of rodents in each trapping session are given in Fig. 8. There was high population of rodents in the first two trapping sessions of the wet season. However, there was a decline of population in the later three trapping sessions of the dry season. The Highest population (N= 172) was recorded during the 1st trapping session (wet season) whereas; the minimum (N= 32) was recorded during the 5th trapping session (dry season). The estimated numbers of all rodent species for each grid using minimum number alive (MNA) was 62, 137, 86 and 121 for ISP, YSP, OSP and BLA respectively.

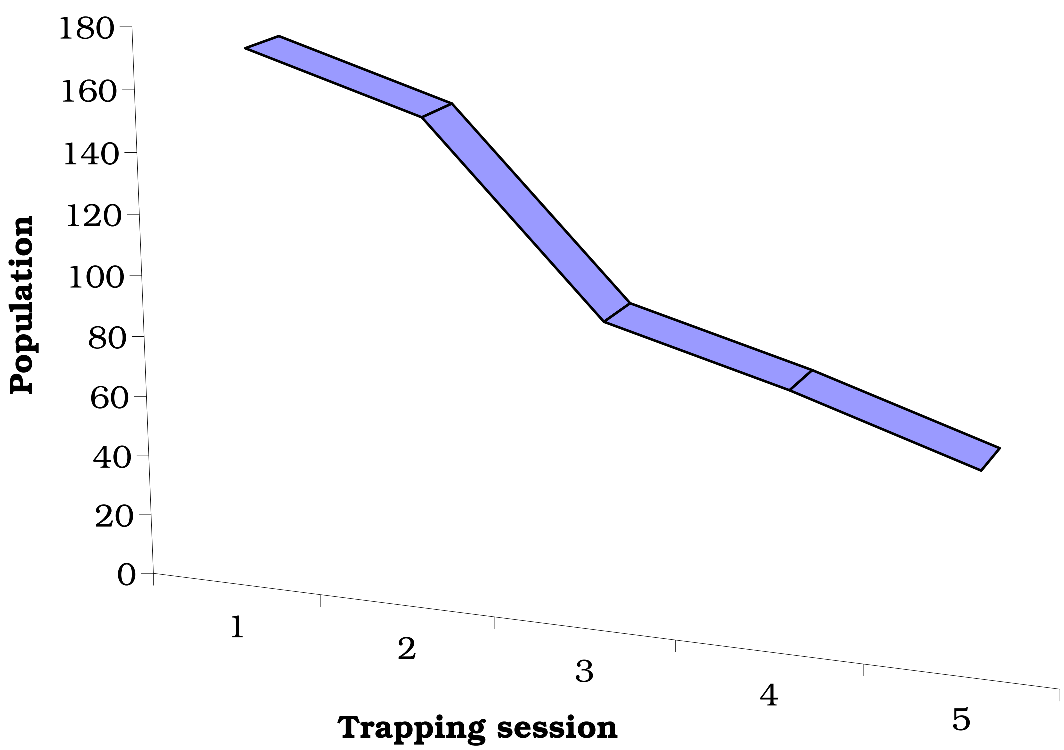

Figure 8. Population estimation of rodents in five trapping periods

4. DISCUSSION

4.1 Abundance of rodents and their habitat association

There are many reasons for the abundance of rodents in a certain area such as altitudinal variations and vegetation types. In agricultural areas, their abundance is usually associated with the reproductive phase of the crop (Workneh Gebresilassie et al., 2004). The abundance of rodents in Wonji sugarcane plantations varied with the different growth stages of the cane. Among them, YSP contained the highest number of rodents and insectivores. The number of rodents and insectivores was expected to be the highest in OSP. According to Blackburn (1984), mature sugarcane provides heavy cover and enough food for a relatively high population of rodents. However, the present observation in Wonji might be related to the following reasons: firstly, the YSP sample was of ratoon cane. As compared to plant cane, the number of cane stalks and density are higher in ratoon fields. Therefore, although the age of the cane is young, there is a relatively high ground cover for rodents and insectivores in ratoon fields. This is also in agreement with the findings of Fauconnier (1993). Secondly, parallel to YSP, there was a mature sugarcane plantation that was 10 m away. Therefore, there might be migration of rodents that could result an increased estimate of abundance in YSP. There is a high level probability for the migration of rodents between adjacent sugarcane fields (Haque *et al.*, 1985). Thirdly, among different cane varieties, which are grown in the sugarcane plantations in Wonji, B52 cane variety is widely grown. This variety is relatively very sweet and soft. YSP had this variety. Therefore, rodents may have preferred this variety to others. There is also a suggestion that rodents prefer sweet and soft canes (Fauconnier, 1993).

In ISP, the abundance of rodents and insectivores was the least compared to others. During the first two trapping sessions only 20 individuals were trapped when this field had 5 to 7 months plantation. This was so because, the cane at this age provided very little cover and food (Whisson, 1996). However, in the latter three trapping sessions of the dry season, a total of 42 individuals were caught. The cane during these periods increased in age, which contributed good ground cover for rodents.

On the other hand, bushland area, which was the fourth sample area, was located very near to a rock hill. This was an advantage for rodents as a good hiding place reducing the risk of predation. As a result there was more catch of rodents. Emmons (1984) showed that there is high density of rodents in bushland areas, which are near or adjacent to rock hills. The availability of different food items in the bushland might have also contributed to the high number of individuals.

There was a remarkable difference in abundance of different rodent and insectivore species from season to season. The multimammate rat, *M. natalensis* was significantly abundant during the wet season. It is already known that rainfall has a positive impact in the breeding of this species (Taylor and Green, 1976; Stenseth *et al.*, 2001; Hubert and Adam, 1985). Rainfall also favored the growth of weeds in the sugarcane plantations. Ground cover was an additional advantage for *M. natalensis* to be abundant during this season. The African multimammate rat shows a strict breeding seasonality, linked to rainfall periods, probably through the stimulating effect of germinating weeds (Leirs *et al.*, 1994).

Two species of the Genus *Mus* (*M. mahomet* and *M. musculus*) were the second most abundant rodents during the wet season. In contrast to the report of Bates (1988), that they occur exclusively in urban and village areas, the present study has revealed that they are also present in the sugarcane plantations. The other rodent species, *S. albipes* was also relatively abundant during the wet season.

The unstripped grass rat, *A. dembeensis* and the Nile-rat, *A. niloticus* were more abundant during the dry season. This observation is well in line with the findings of Delany (1986) and Afework Bekele *et al.* (1993). They attain maximum numbers during the mid-dry season. Other rodent species such as, *P. harringtoni* and *R. rattus* were also relatively abundant during the dry season.

In general, all the trapped rodents and insectivores inhabit all the three growth stages of the sugarcane plants. There was no rodent or insectivore species that was restricted to a specific age of the sugarcane plant. But the only difference observed among them was regarding their abundance. ISP, YSP and OSP constituted 15.3%, 33.7%, and 21.2% of the total catch, respectively. However, in considering seasons, some species of rodents were not observed in the early stage of ISP during the wet season. This was due to the initial growth stage of the plant that was not a suitable habitat compared to the other sugarcane stages. But in the later ages of ISP, more rodent and insectivore species were attracted due to a relatively better ground cover. Tobin *et al.* (1990) had confirmed that during the long growth periods of sugarcane, cane stalks are tall and big, and rows are shaded or hidden by foliage, which provide a suitable resting and breeding place for rodents.

The multimammate rat, *M. natalensis* was the dominant species in all ages of the sugarcane plant. It comprised 24.2%, 32.8%, and 31.4% of the total catch in ISP, YSP and OSP, respectively. In bushland, it was

19.8% of the total catch which was the second in abundance to *Arvicanthis* species (30.6%) in this habitat. *M. natalensis* is well documented as a major agricultural pest in East Africa (Fiedler, 1994). It has wider distribution over most of Ethiopia, southwestern Ethiopia, Gambela, Dembia, Maji, (shore) Lake Shalla, along Takeze and Godere Rivers in altitudes ranging between 500- 2900 m asl. (Yalden *et al.*, 1976).

The Genus *Arvicanthis* (*A. dembeensis* and *A. niloticus*) were the second most dominant species in all ages of the cane. These species are also reported as agricultural pests in Ethiopia (Afework Bekele *et al.*, 1993; Lavrenchenko *et al.*, 1998). *A. dembeensis* is a lowland species with most records between sea level and 2200 m asl. (Capanna *et al.*, 1996). According to Yalden *et al.* (1976), its distribution in Ethiopia include Awash National Park, Holeta, Akordat, Arbaminch, Koffole, Koka, Shore of Lake Zeway, Shore of Lake Tana and Awash River basin. Compared to *A. dembeensis*, *A. niloticus* was relatively less in number in sugarcane fields. This species usually favors savanna habitats at lower altitude. As stated by Capula *et al.* (1997), its distribution extends up to the Nile Valleys and the Horn of Africa to Senegal across the sub-Saharan belt.

Mus species (*M. musculus* and *M. mahomet*) were also dominant in ISP and OSP. They were also trapped from YSP and bushland in less numbers. The occurrence of house mouse, *M. musculus* in sugarcane plantations was unusual. In fact, this species usually occurs in urban and village areas, which consume and contaminate large quantities of human food and animal feed. Yalden *et al.* (1976) described its occurrence in Ethiopia at Awash National Park, Addis Ababa, Dire Dawa, and Shore of Lake Tana with an altitudnal range between 1510 and 3000 m asl. The occurrence of *M. mahomet* in sugarcane plantations was not surprising. This species has been usually recorded to occur in agricultural fields, as well as sugarcane fields of southeast Asian countries (Engeman *et al*., 1998). In maize fields of central Ethiopia, *M. mahomet* comprised 35% of the total live-trapped small mammals (Afework Bekele *et al.*, 2003).

The Ethiopian endemic rodent species, *S. albipes* was trapped in a significant number next to *Mus* species in ISP and OSP. It had the third position in YSP, next to the two *Arvicanthis* species. Bushland also contained this species (Table 3). According to Afework Bekele and Corti (1997), its habitat varied from forest to scrubs in altitudes between 1500-3300 m asl. However, there was no previous record of this species in agricultural fields such as sugarcane plantation in Ethiopia. It has been recorded from various parts of Ethiopia including Bahir-Dar, Lake Zeway, Alemaya, Debre Markos, Dembecha, Mendi, Nijabara, Goba, Bedele, Kibre Mengist and Bako (Yalden *et al*., 1976).

The other Ethiopian endemic rodent species, *P. harringtoni* was the least trapped rodent next to *R. rattus* in all growth stages of the cane. More number of this species was found in bushland. It inhabits scrab or bushland areas. Moreover, it was not recorded as agricultural pest in Ethiopia so far. It is widespread on the Ethiopian plateaux, on both sides of the Rift Valley, at altitudes of 1800-2800 m asl, but it remains poorly known (Yalden *et al.*, 1976).

The black rat, *R. rattus* was the other rodent species trapped from all growth stages of the sugarcane and bushland habitats. It was the least trapped rodent during the present investigation. Compared to earlier studies in other countries in which *R. rattus* is the major pest species, its less occurrence in Wonji sugarcane plantations was unusual. In

Hawaiian sugarcane plantation, 40% of damage was recorded by *R. rattus* alone (Wood, 1994).

C. flavescence and *C. fumosa* were trapped in all growth stages of the sugarcane plant and in bushland as well. But, their occurrence in sugarcane plantations was unusual. Because, firstly, these species were not recorded in agricultural areas of Ethiopia so far. Secondly, in the present study they were found in a new altitudinal range. Delany (1964) stated that *C. flavescence* is typically a forest species and Yalden (1988) described *C. fumosa* as a moorland species common in areas of altitudinal ranges 3800 and 4000 m asl.

4.2 Trap success

Trap success varied among the different growth stages of the sugarcane plant. The trap success was high during the wet season than the dry season. In this season, YSP had the highest trap success whereas ISP had the least. This may be due to effect of the age of the cane. The ground cover in ISP in this season was devoid of vegetation. In addition, trap success in OSP was less than in YSP, probably for two reasons. First, YSP has better ground cover that invites more rodents and insectivores even from the adjacent plantations. Second, during the fourth trapping period, OSP was highly watered which was unfavorable for rodents. Therefore, during such periods only few rodents were trapped. On the other hand, trap success in bushland was high as compared to old and immature stages of the sugarcane plantations. For most species of rodents, there was high trap success of breeding females. This contradicts with the finding of Jacob *et al.* (2003) that when breeding, female rats may have stayed close to their offspring in the burrows, lowering the probability to encounter and enter a trap.

The overall trap success in Wonji sugarcane area including bushland was 13.8%. However in sugarcane areas, it was 12.9%. This was a high success rate compared with Siddique and Arshad (2003), who have revealed as 4.1% success in the sugarcane plantations of Pakistan. In comparison with other agricultural crops, also the success rate is high. For instance, Odhiambo and Oguge (2003) obtained 6.2% success in 20,100 trap nights from maize crop in the Kenyan Rift Valley, Jacob *et al.* (2003) obtained 5.1% success in 3060 trap nights from rice field in West Java, Afework Bekele *et al.* (2003) obtained 11.5% success in 2400 trap nights from maize farm at Zeway, Ethiopia.

Two rodents per trap were frequently occurred in the sugarcane plantations. This was usually observed in *Mus* spp. In one occasion, live C*. fumosa* and killed *P.harringtoni* was obtained in a single trap. Except for frogs, captures of non-target animals were rare.

4.3 Age Structure and Reproduction

All age groups were represented in the population of most rodent and insectivore species. The age distribution in a population of most species at different seasons was directly related to the seasonality in reproduction. When reproduction is seasonal, it is expected that all age groups appear in the population within that specific season. On the other hand, in some species of rodents, all age groups appeared irrespective of the season (Tadesse Habitamu, 2005). This may lead to a conclusion that these species show aseasonality in breeding. The presence of a relatively equal number of pregnant females in both trapping seasons may support this conclusion.

In general, young, subadult and adult individuals constituted 39.4%, 12.9%, and 47.7%, respectively. During the wet season, young members accounted 28.6% of the total population. For most species, there was a correlation between rainfall and the seasonality in reproduction. This was in agreement with those who have worked on African rodents (Hapold, 1974; Taylor and Green, 1976; Perrin *et al.*, 1992; Afework Bekele and Leirs, 1997). During the dry season, young members accounted 44% of the total catch. This increment in a population may be due to those species, which were able to breed throughout the year.

No pregnant female was trapped in the case of *A. dembeensis* during the dry season. Lavrechenko *et al.* (1998) and Taylor and Green (1976) have showed positive association of rainfall with reproduction for *Arvicanthis* spp. However, the report of Delany and Roberts (1978) showed that there is a continuous breeding throughout the year that contradicts with the present finding. Similarly, although four adult females of *C. flavesence* were trapped during this season, none of them were pregnant. Pregnant members of *R. rattus* and *P. harringtoni* were trapped in both seasons. Grzimek (2003) has reported that these two species are able to breed throughout the year if conditions allow. Therefore, this may be the reason why pregnant females of these species were trapped irrespective of seasons. Furthermore, in both seasons, pregnant females of *M. natalensis* were trapped although they were more in number during the wet season. This may be an evidence for the presence of continuous breeding throughout the year (Happold, 1974; Perrin *et al.*, 1992). But it contradicts with Leirs *et al.* (1994) that *M. natalensis* showed a strict breeding seasonality, closely linked to rainfall periods. Pregnant members of *S. albipes* were trapped during both seasons. This showed aseasonality of breeding that is in line with the finding of Happold (1974) and Afework Bekele (1996a).

4.4 Pest Status

In agricultural areas, rodent damage is rarely uniform in time, but follows crop phenology. Leirs (2003) revealed that rodents cause more damage at some stages in the growth of rice than to others. In sugarcane plantations, rodents and insectivores were major pest species. The extent of their damage varied with seasons. Maximum damage of the cane per grid was recorded in YSP during the wet season followed by OSP. This may be due to the fact that it was a breeding season for most rodent species. This is in agreement with the finding of Leirs (2003), who reported that high rodent damage in agricultural fields is attained during the breeding season. No damage was observed in ISP during this season. Greaves (1982) has reported that the levels of rodent damage in agricultural fields are more intense when the crop is approaching the harvest stage. However, in the dry season, rodent damage was observed in ISP. This was because the cane during this season increased age, which contributed a suitable habitat for rodents.

Among rodent species in the plantation, *M. natalensis* and *Arvicanthis* spp. were the major pests. Their abundance in the plantation was very high. This was in line with the findings in many agricultural fields of East Africa. For instance, Makundi and Massawe (2003), Odhiamba and Oguge (2003) and Afework Bekele *et al.* (2003) have reported that these species are the most serious rodent pests in agricultural fields of Tanzania, Kenya, and Ethiopia, respectively. Other rodent pests such as, *S. albipes*, *P. harringtoni*, *Mus* spp. and *R. rattus* had also contributed for the damage of the sugarcane plantation. Shrew spp. (*C. flavesence* and *C. fumosa*) damage in the plantation was more of indirect by exposing the roots of the cane for air while they make a burrow.

Porcupine (*Hystrix cristata*) was rarely observed in the plantations, near villages. It usually feeds upon vegetables in the villages and probably they may use the plantation for hiding while they escape from villages. Larger mammals such as hippopotamus, warthogs and monkeys were also seen in the plantation. Warthogs live in the plantation. Besides their damage by direct feeding, they destroy large number of cane stalks when they move through the plantation. This creates a good opportunity for rodents. Hippopotamus usually attack plantations along the border of the Awash River. Plantations in which the border was surrounded by trees were also frequent victims of monkeys.

Sugarcane stalks damaged by rodents are easily distinguished from those damaged by warthogs and monkeys. Usually rodent damage is identified by open holes at lower internodes and small chips on the ground, where they have fed (Plate 3 a, b, c). In some cases, the damaged stalks fall on the ground, as they stand with least support. This provides an additional advantage for rodents as a shelter. Warthogs chew the whole part of the lower internodes and also feed on young leaves of the cane. Monkeys cut the standing cane, carry and immediately climb on trees to eat. However, they usually cut the younger canes, which are less strong.

In general, the damage of rodents and insectivores in the plantation was 4.0%. This was comparable with the report of 2-5% by Stensteh *et al.* (2003) from Australian sugarcane plantations. It was less as compared to Hawai (40%), South America (12-20%) and Andhra Pradesh (20.7%) sugarcane fields (Stensteh *et al.*, 2003). Major rodent pests in these regions were *Holochilus* spp., *Bandacota bengalennsis*, and *Rattus* spp. Especially, *Rattus* spp. is a well known rodent pest, which is found in a large number in many sugarcane plantations (Tobin *et al.*, 1990).

However, at Wonji Sugarcane Plantations, it was the least trapped species.

4.5 Diet Analysis

The stomach content analysis of rodents trapped from the sugarcane plantation confirmed the predominance of sugarcane fibers in their diet. This further indicates their damage extent in the plantation. The plantation is a relatively undisturbed and suitable habitat, which supplies continuous food for rodents until harvest. Therefore, by using this temporary advantage, rodents minimize their cost of energy for searching food. Similarly, Leirs (2003) explained that rodents cause damage because they select the food source that at a certain place and time give them the net benefit when balancing energy intake versus the cost of searching food. On the other hand, stomach contents of *A. dembeensis* and *P. harringtoni* trapped from the bushland contained primarily grass leaves and other monocot seeds. Workneh Gebresilassie *et al.* (2004) also found higher percentage of grass and monocot seeds in the stomachs of *A. dembeensis*. In the stomach contents of *C. flavesence* sugarcane fibers and grass were obtained. However, the majority of the stomach contents of *C. flavesence* was difficult to identify (Table 7). In all analyzed stomachs, there was a considerable amount of animal matter. This may fulfill their protein requirement. In general, the feeding habit of rodents as revealed by the stomach content analysis indicates that sugarcane plantation was the major food item regardless of seasons.

4.6 Population Estimation

The rodent population showed seasonal fluctuation in the present study area. Among different trapping sessions, the first trapping period of wet season had the highest rodent population. On the other hand, the least estimate was during the last trapping session of the dry season (Fig. 8). This was not in agreement with the findings of Gliwicz (1985), Happold and Happold (1991) from some Africa countries, Linzey and Kesner (1996) in Zimbabwe and Tadesse Habitamu (2005) in Ethiopia. The causes of population fluctuation of rodents are variable. Different investigators suggested that vegetation cover; climate, food abundance, food quality and predation are the major causes for rodent population fluctuations. Rainfall had a significant role for the occurrence of high population of rodents during the wet season. It has a strong impact in the breeding of many rodent species. Moreover, rainfall facilitates the growth of ground vegetation in the sugarcane plantations, which further provide suitable habitats and food.

However, during the dry season, besides the less availability of rainfall, there were two major reasons for the reduction of population of rodents in the plantation. First, during the fourth trapping session, in OSP only few individual of rodent species were trapped since the plantation was highly watered. In such conditions, there might be migration of rodents to the adjacent cane fields. Second, during the last trapping session, OSP was already harvested. Therefore, rodent trapping was conducted on this harvested fallowland, which resulted on no catch at all.

Population estimate of rodents using Minimum number alive (MNA) was higher in YSP. On the contrary, the least estimate was recorded in ISP. This was probably due to a relatively good ground cover in YSP that is more suitable for rodents.

5. CONCLUSION AND RECOMMENDATIONS

The data collected during the present investigation provided valuable information on the species composition, habitat association and abundance of the rodent species in Wonji Sugarcane area. Variation in the abundance of rodents and insectivores in different growth stages of the cane implies the key role of ground vegetation in the plantations. For this fact, YSP, which had a relatively good ground cover, showed the highest species abundance. However, in the early stage of the cane (ISP), due to less availability of ground vegetation and foliages, less number of rodents occurred. Moreover, the abundance of rodents and insectivores in ratoon fields is higher than in plant cane fields. This implies that ratoon fields are more suitable for rodents and insectivores, probably due to high number of cane stalks and density per row.

The same species richness in all growth stages of the cane indicates rodents might not be concerned with the age of the cane as far as there is good ground cover. Moreover, they are the only rodent and insectivore species that occur in Wonji Sugarcane Plantations. In the present study, rainfall had a significant role for the seasonal abundance of most rodent species. For this reason, there was high trap success in YSP, OSP and bushland during the wet season. The occurrence of more number of pregnant females resulted in high population of rodents during this season, which further confirmed the significance of rainfall in breeding for most species.

The present investigation has revealed that rodents and insectivores are sugarcane pests. The predominance of sugarcane fibers in the stomach of *M. natalensis*, *S. albipes* and *M. Mahomet* is an indication of their pest status. Although the stomach content analysis was conducted only for the snap trapped species, other species, which were not snap trapped were also expected to be sugarcane pests as far as they were live trapped from the sugarcane plantations in each trapping sessions. Moreover, although the damage by rodents in Wonji Sugarcane Plantation was not as high as reports from other countries, their cumulative impact through years would be high, unless control measures are taken. The damage caused by other large mammals such as warthogs, hippopotamus and monkeys also indicate the need for further studies concerning their pest status in the plantations, although the present study did not quantify the extent of damage by these mammals.

In general, based on the results of the present study, the following recommendations are suggested:

- There should be effective weed and grass growth control programs in the plantations from time to time.
- The foliages of sugarcane should be removed and burned so as to eliminate nesting and breeding sites for rodents in the plantations.
- Non-sugarcane area around the plantations should be kept clean in order to reduce the harboring and to limit their movement to the plantations.
- Rodent control measures should be taken before the breeding season of each rodent species.
- The biology and ecology of rodents in the plantations and nearby habitats have to be thoroughly studied for designing appropriate control measures.
- Plantations along the border of Awash River should be fenced or dug to prevent from hippopotamus damage.
- Plantations along border areas with trees have to be properly kept by cane guards to protect them from monkeys.

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a)

b)

Plate 1. Immature and Young growth stage of the Sugarcane plant (a & b)

a)

b)

Plate 2. Old stage sugarcane plant (a) and bushland area (b)

a)

b)

c)

Plate 3. Sugarcane damage by rodents.

DECLARATION

I, the undersigned, declare that the information provided in this work is an original work, and that it has not been presented in other universities or colleges, seeking for similar degree or other purposes.

Name	Date	Signature